NABC Report 27

Stewardship for the Sustainability of Genetically Engineered Crops: The Way Forward in Pest Management, Coexistence, and Trade

Edited by Gary A. Thompson, Susanne E. Lipari, and Ralph W.F. Hardy

2015

North American Agricultural Biotechnology Council Report

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NORTH AMERICAN AGRICULTURAL BIOTECHNOLOGY COUNCIL

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Providing an open forum for exploring issues in agricultural biotechnology

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Proceedings of the 27th annual conference of
the North American Agricultural Biotechnology Council,
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June 2 and 3, 2015

Edited by
Gary A. Thompson, Susanne E. Lipari, and Ralph W.F. Hardy

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North American Agricultural Biotechnology Council

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The 27th annual meeting of the North American Agricultural Biotechnology Council—"NABC 27"—was hosted by Gary A. Thompson (Associate Dean for Research and Graduate Education, and Director of the Agricultural Experiment Station at The Pennsylvania State University, University Park, PA).

We thank Dr. Thompson and his team for a most successful conference.

Planning Committee

Gary A. Thompson (Chair) and Dave Mortensen, The Pennsylvania State University; Ralph W. F. Hardy, Allan Eaglesham, and Susanne Lipari, NABC; Greg Jaffe, Center for Science in the Public Interest; Carol Mallory-Smith, Oregon State University; Steve Pueppke, Michigan State University; Anthony Shelton, Cornell University

Smooth operation of the conference resulted from the contributions of the following:

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Gary A. Thompson, Dave Mortensen, David Abler, and Leland Glenna (The Pennsylvania State University)
Carol Mallory-Smith (Oregon State University)
Steve Pueppke (Michigan State University)

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On behalf of NABC, we thank Gary A. Thompson for first-rate

Ralph W. F. Hardy
President, NABC

February 2016

PREFACE

NABC Report 27 provides an overview of stewardship and sustainability of genetically engineered crops. The meeting combined presentations by 20 US and Canadian leaders from academia, government, industry and public interest groups, question and answer sessions providing an opportunity for dialog by all attendees, and a concluding session with a panel representing academia, grower-input industry, and a not-for-profit food consumer organization. The objective of the meeting was to provide a broad overview of issues requiring stewardship and sustainability. Current status and the road forward were emphasized for four dominant issues—resistance management, coexistence, trade and markets, and social and economic concerns. All of these issues have been central to agriculture for decades—well before the introduction of genetically engineered products for agriculture in the 1990s. For example, I recall chairing a National Research Council committee on ecologically based pest management, which for the most part preceded the introduction of genetically engineered ag products. It is important to recognize that the issues discussed at NABC 27 were not initiated by genetic engineering. Genetically engineered crops are not unique for these issues, but have their own subset. These must be dealt with to ensure sustainability of these products to continue as an integral part of crop ag practices. The beneficial impact of GE crops in farm sustainability was addressed by a 2010 NRC report, e.g. herbicide-resistant crops enabled broad use of no-till practices and the use of herbicides with less residual persistence in our soils, and plants genetically engineered for pest resistance have reduced the use of chemical pesticides. NABC 27 explored in an open forum the road forward to promote sustainability of these products, the ones now in use, those in development and still others being conceived in our laboratories. This stewardship has responsibilities for farmer-growers, ag input industries, processors, academe, and government. I hope that the reader will find NABC Report 27 to be a balanced, thoughtful, and useful presentation of the road forward.

Ralph W. F. Hardy
President, NABC

Susanne E. Lipari
Executive Coordinator

Figures are printed in grayscale, hence information may have been lost from graphics lifted from colored PowerPoint slides. Color versions of the figures are available at http://nabc.cals.cornell.edu/Publications/Reports/pubs_reports_27.htm.

The *Student Voice at NABC* program provides grants of up to $750 to graduate students at NABC-member institutions (one student per institution) to offset travel and lodging expenses. Also, registration fees are waived for grant winners. Information on the *Student Voice at NABC 28* will be available at http://nabc.cals.cornell.edu/StudentVoice.htm.

CONTENTS

PART I–CONFERENCE OVERVIEW

NABC 27: A Focus on the Issues

Gary A. Thompson
The Pennsylvania State University

Ralph W. F. Hardy
NABC

2015 was a milestone marking the 20th anniversary of the commercial introduction of genetically engineered (GE) crops. Global acceptance of this technology by 18 million farmers has resulted in more than 181 million hectares planted in GE crops (http://www.isaaa.org/resources/publications/briefs/default). This includes greater than 90% of all soybeans, upland cotton, and corn planted in the United States (http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx). While many traits are under development or at early stages of commercialization, GE crop technology has primarily focused on a narrow range of traits that impart herbicide tolerance and insect resistance either individually or as stacked-gene varieties. These have become effective management tools for reducing pest problems with significant benefits for agriculture.

In 2010, the National Research Council released an insightful report, *The Impact of Genetically Engineered Crops on Farm Sustainability in the United States*, which discusses the economic, environmental, and social impacts of GE crops on American farms. This report provides an excellent overview of these complex issues as we consider responsible stewardship for the sustainability of these technologies. For example, the broad use of no-till practices enabled by the adoption of herbicide-resistant crops is having positive impacts on the quality of our soils and water. Furthermore, the adoption of insect-resistant crops minimizes chemical pesticide use, reducing off-target effects of pesticides on beneficial insects. However, such wide use of a focused technology based on a limited number of genetic traits has not been without its challenges. Deployment of GE technologies—as with most agricultural advances—requires the development and use of effective management strategies. Development of resistance within the targeted pests has become an issue, especially in weed control, where herbicide-tolerance genes have been widely employed

in crop plants. Thus, adoption of cost-effective management strategies by growers is essential for the long-term utility and stewardship of GE crops. Increasingly, this includes combinations of management strategies for farming practices utilizing conventional, organic, identity-preserved (IP), and GE cropping systems that effectively "coexist" in close proximity and in the marketplace. Coexistence of farming practices provides growers with the flexibility to respond to market opportunities and improve overall profitability. Evaluating the economic impact of GE crops can be complex, especially in light of international commodity markets and trade policies. Economic impacts are also intertwined with social issues surrounding consumer views and acceptance of GE crops in local, regional, and global markets. While numerous benefits have been realized by agricultural producers' adoption of GE crops, few other issues in our society spark the passions of individuals and groups as do GE crops.

The North American Agricultural Biotechnology Council's 27th annual conference was held in State College, PA, June 2–3, 2015, hosted by the College of Agricultural Sciences at The Pennsylvania State University. The conference brought together a broad range of experts to examine and discuss the varied and often complex perspectives on key issues that impact the sustainability of GE crops, including stewardship approaches to resistance management, coexistence, trade and markets, and social and economic dimensions of sustainability. Thought leaders from academia, government, and the agricultural industry in each of these critical areas presented varied views on the topics in a constructive dialog that engaged the audience through panel discussions. The conference began with keynote presentations, defining the challenges and setting the stage for moderated plenary sessions, each followed by facilitated panel discussions. Speakers addressed the delegates at the conference banquet and during the luncheon on the second day. Graduate student participants presented their views on the conference topics in the segment *Student Voice*. Finally, the closing panel session, *Putting It All Together*, capped off the conference with a lively discussion of key issues presented during the two-day meeting.

Keynote Addresses

Kathleen A. Merrigan (George Washington University) challenged the delegates with her keynote presentation, *Thinking across Time: A 20-Year Perspective on Biotech Policy*, taking a broad historical view of critical moments in the biotech industry that have framed the current issues. She stressed the need for independent voices with limited ties to industry to serve as a science-based forum to address agriculture and food policy. AGree (http://www.foodandagpolicy.org/), with its broad cross-sectional representation of the food and agricultural system, is an organization that strives for consensus among groups with differing views. Such organizations can address complex questions, such as whether biotechnology can aid the organic industry rather than put farmers with differing production approaches at odds. However, the complex issues surrounding coexistence are unlikely to be fully resolved by voluntary or market forces, but will almost certainly require government regulation. The statutory authority of the USDA empowers the agency to issue "fair and transparent regulation" as a solution to coexistence.

Richard Roush (The Pennsylvania State University) introduced the challenges faced by agriculture worldwide in developing and managing resistance to GE-based insect and weed control strategies in his talk, *What Are the Major Impediments to Resistance Management for Crops in the Social Sciences and Governance?* Pesticide resistance has been investigated for many years, and while the fundamentals of the genetic mechanisms and management theory are well understood, at the field level resistance management has been much more effective in preventing rapid development of pesticide resistance among insects than in preventing herbicide resistance among weeds. Why? Resistance can be delayed by killing the heterozygotes that carry the resistance alleles. Changing tactics has been a key to insect resistance management. Multiple toxins with high mortality rates across different life stages are needed to maintain a very low frequency of resistance. Pyramiding GE traits combined with refuges appears to be an effective strategy for delaying insect resistance. Weed resistance management strategies have been less robust, especially in Roundup Ready crops. Two factors have resulted in the development of more than 14 resistant weed species: lack of rotation, leading to prolonged use of a single herbicide over successive years, and applications to more mature weeds carrying the resistance trait, for which herbicide control tends to be less effective. The refuge concept also appears to be less applicable for weeds than it is for mobile insects; however, tillage may put seed back into the seed bank, reducing selection intensity. While effective strategies are understood, some level of government intervention in combination with grower education seems to be required to enforce resistance management practices.

Coexistence raises complex management, policy, economic, and consumer issues that were discussed by **Greg Jaffe** (Center for Science in the Public Interest) in his presentation, *Coexistence of Biotech, Organic, and Conventional Crops: Facts, Issues, and a Path Forward*. Coexistence "embodies the idea that consumers should be able to get the products they want." Coexistence is a complex issue that predates GE crops. For example, the alternative uses and handling of a single crop plant commodity (i.e., rapeseed) for different products (edible vs. industrial) provides some historical context for the practice of coexistence. However, it is important to understand the functional meaning of the term coexistence in the current context of biotech, organic, and conventionally produced crops. Coexistence only involves relationships within a specific, legally approved crop plant that can be produced by different farming practices and for different uses "with a specific market goal." Most controversy today concerns the coexistence of biotech crops with conventional or organically produced crops and especially focuses on issues surrounding the economic costs farmers incur as a result of unintended presence and on potential compensation mechanisms. The issues surrounding coexistence will continue to grow as the number of GE products coming into the marketplace increases, as will the need for increased educational outreach to support coexistence.

The final keynote presentation, *Agricultural Biotechnology: Facilitating Trade for Food and Feed*, by **Sharon Bomer Lauritsen** (Office of the US Trade Representative) introduced the many interconnected issues, such as asynchronous authorization, trade disruption, liability, boycotts, and policies, affecting global agricultural and international trade of

GE crops. The sheer magnitude of US exports of GE-derived commodities, along with the increasing number of countries producing GE crops, is significantly impacting this global trade. Current global trade issues being addressed by the US government include the lack of science-based regulation that is often encountered in developing countries; asynchronous authorizations (differences in the time taken to review and authorize the cultivation and import of new products); low-level presence (detection of an event approved in an exporting country but not an importing country); labeling; legal liability in a country so severe that the approval process is not pursued there; and new opt-out provisions for EU member states. Technology developers can play an important stewardship role to facilitate trade by "ensuring that products are authorized in key export markets before introducing them for cultivation."

Plenary Sessions

Three plenary sessions were organized around the topics introduced by the keynote speakers: *resistance management, coexistence*, and *trade and markets*. A fourth plenary session focused on the complex issues of *social and economic dimensions of sustainability*.

Resistance Management

The first plenary session, *Resistance Management*, moderated by Dave Mortensen (The Pennsylvania State University), included three talks that explored US and Canadian approaches to regulating and managing widely adopted traits for insect protection and herbicide resistance in some of our major crop plants. Agricultural biotechnology has introduced two widely adopted traits in grain, fiber, and forage crop production: plant-incorporated protectants for insect protection, and herbicide resistance enabling the use of broad-spectrum herbicides. While both are widely adopted, overreliance on these traits has resulted in a significant rise in pest resistance. Specific steps that can be taken to address pest resistance and clarify the constraints to their adoption were discussed.

Jack Housenger (US Environmental Protection Agency) discussed the EPA's perspectives in his talk, *Regulating Resistance*. Extending the useful life of pesticides by delaying resistance without excessively burdening growers is a goal in the EPA's regulatory strategy. This is being accomplished by requiring resistance management plans that incorporate scouting, reporting, cultural, and mechanical practices as key elements for EPA approvals of newly registered crops. For example, education and training for the early identification and reporting of resistant weeds is being combined with labeling requirements that include the mode of action and best management practices (BMPs) to slow the development of resistant weeds.

Nicholas P. Storer (Dow AgroSciences) provided a biotech industry perspective in his talk, *Insect Resistance Management for GE Crops: Industry Principles, Policies, and Programs*, focusing on the commitment across the industry to implement strategies for durable GE crop deployment based on effective insect resistance management (IRM). Refuges, "high dose" traits, and pyramiding toxins with multiple modes of action are widely advocated as effective IRM techniques. However, the practice of pyramiding toxins is currently

hampered by the narrow range of useful insecticidal proteins. Major companies within the industry are clearly committed to the deployment of durable GE crop technologies that can be reasonably integrated into a farmer's resistance management program as the basis for stewardship of the technology.

Hugh J. Beckie (Agriculture and Agri-Food Canada Research Centre), in his presentation, *Herbicide-Resistant Crop Management: A Canadian Perspective*, focused on the comprehensive approaches to weed resistance in Canada for GE canola, corn, and soybeans, including reporting requirements, BMPs to minimize resistance, and systematic monitoring for herbicide-resistant weeds. Resistance management plans have been required to deregulate herbicide-resistant crops for more than a decade in Canada. Following deregulation, a framework that incorporates weed surveys was developed to facilitate the early identification of herbicide-resistant weeds through environmental monitoring of released GE crops. While such regulatory strategies are important, proactive herbicide-resistant weed management is rare and should be reinforced by third-party random field surveys, mandatory training sessions for growers on BMPs, robust industry stewardship strategies that go beyond stacked-HR-trait cultivars, and government programs that incentivize reduced herbicide use.

Coexistence

The second plenary session, *Coexistence*, moderated by Carol Mallory-Smith, presented academic and industry perspectives on the issues that affect both grower and consumer choices and the challenges presented to the marketplace in an increasingly diverse food system. A recurring theme of this session, as well as of others, was stewardship of GE crops to address adventitious presence in conventional and organic crops. Practical solutions that can be implemented at the farm and market levels will ensure the greatest success of these measures.

Carol Mallory-Smith (Oregon State University) delivered the introductory session talk, *Coexistence: The University Role*, focusing on the challenges land grant universities face in fulfilling their mission of providing unbiased information through research, education, and extension for the broad range of stakeholders that coexist in this technologically diverse landscape. Coexistence can be thought of in the full agricultural context as providing farmers with choices among production methods, such as conventional, organic, and GE, while meeting both legal obligations and market standards. This definition of coexistence extends beyond the issues of genetics or production methods most often addressed by the agricultural and life sciences to the less defined and potentially more complex issues addressed by the social and political sciences. Thus, a truly interdisciplinary approach is required for land grant universities to remain true to their mission of providing unbiased, relevant information to the agricultural community.

Lynn Clarkson (Clarkson Grain Company) discussed the issues involved in managing for purity when meeting client quality standards in commercial-scale handling of conventional, GE, and organic crops in his talk, *Segregating GMO Crops—Cultural and*

Functional Challenges. Identity preservation (IP) (tracking the specific identity of bulk agricultural commodity shipments to maintain unique characteristics that would be lost by commingling during storage, handling, or shipping) is essential when multiple pathways to the marketplace exist for an individual commodity. IP provides market access by growing and delivering a crop as it is desired, creating a competitive advantage in the marketplace. Managing for purity begins with the grower, regardless of whether a crop is GE, organic, or based on functional traits. Segregation buffers support farmers' choices and minimize the potential impacts of their neighbors' market choices. Premiums for delivering quality and purity in contracts are a strong inducement for growers. Meeting buyers' standards for purity is a challenge for IP. Tolerance levels for contamination due to adventitious presence, including testing protocols, lack consistent global industry standards, and could provide a role for government. It is important that everyone within the industry, from seed providers to farmers to shippers, participate in achieving the common goal of delivering products that the market desires.

Greg Loberg (West Coast Beet Seed Company) told delegates about a highly successful program for coexistence through the Willamette Valley Specialty Seed Association in his presentation, *Coexistence in the Oregon Seed Industry*. Lessons from the Oregon seed industry seem to be rooted in proactive stewardship policies that support coexistence. These policies should be developed by a stewardship committee in anticipation of the release of a GE trait. Sustaining a stewardship policy needs the proactive engagement of all affected parties, including trait owners, growers, and relevant organizations and agencies. An important consideration when establishing new policies is the development of reasonable tolerance thresholds for GE traits, to avoid inflicting zero tolerance standards on an industry. Furthermore, the Oregon seed industry has a long history of demonstrating the value of arbitration as the primary means of resolving conflicts. The "will to coexist" by overcoming ideological differences with tolerance is a particularly important way to avoid political and legal problems.

Trade and Markets

The third plenary session, *Trade and Markets*, moderated by **Dave Abler** (The Pennsylvania State University), addressed current issues on the certification of GE crops and regulations affecting their commercialization in the international marketplace, including asynchronous approval, inconsistent testing, transfer of liability, and identity preservation.

Michael Schechtman (USDA/ARS) discussed the challenges of marketing GE crops in commodity agriculture worldwide in *Trade and Markets for Genetically Engineered Crops: A USDA Perspective*. The USDA plays a key regulatory role in developing and marketing by ensuring the safe and appropriate use of genetic engineering in the US and bringing the products derived from GE plants to the worldwide marketplace. In 2014, US exports of corn and soybeans, mostly GE, exceeded $37 billion. While the US leads in the development and production of plant biotechnology products, other countries, notably Brazil, are producing and developing domestic GE products. Furthermore, GE crop varieties are being adopted in both Asia and Africa, with large research and development investment taking

place in China. Yet global trade issues abound for GE products. Issues with the European Union continue and may increase if individual member states are allowed to ban GE crops using non-science-based criteria, even when those same crops have been determined to be safe by EU authorities. Asynchronous approvals in China, the largest importer of US plant commodities, create potential trade issues with the US. Low-level presence of lawfully grown GE crops in the export stream also presents risks for trade disruptions.

Randal Giroux (Cargill Incorporated) addressed the challenges of managing the coexistence of commodity crops within supply chains and global food systems in *Enabling Coexistence: Balancing Innovation and Market Access*. For biotechnology to fully realize the benefit of increased global food security, its products must be effectively integrated into the global food system. However, many international challenges exist in balancing innovation with market access, including asynchronous approvals and zero tolerance for approved GE traits. Governments, with the assistance of independent scientific groups, are in the best position to provide cogent policies that assure both industries and consumers. However, national approval systems lack uniformity, impeding the development of responsible global commercialization models. The overall value of global exports to US agriculture is substantial, which should stimulate the US government to lead by example in developing proactive policies for the commercialization of GE crops within globally interdependent agricultural supply chains.

William A. Kerr (University of Saskatchewan) explained how divergent regulation of GE commodities on the world market leads to trade barriers and reduces trade flow in his talk, *Worlds Apart on GMOs—Can Trade Agreements Bridge the Gap?* Rules regulating international trade of GE crops do not exist, even though there is a long history of actions taken by the World Trade Organization to establish paths forward to address trade barriers in the global marketplace for GE crops. Political realities in some countries, especially those with strong anti-GE agendas, are supplanting science as the primary basis for domestic policies and trade rules. Furthermore, the ever-increasing worldwide presence of GE crops in the global marketplace becomes more problematic in light of zero tolerance policies for adventitious presence of GE materials in shipments of non-GE crops. Harmonization of trade standards among different countries could resolve current policies that result in trade barriers; however, harmonization requires establishing mutually acceptable regulatory frameworks for trade in GE crops that exceed the scope of trade negotiations.

Social and Economic Dimensions of Sustainability

The fourth and final plenary session, *Social and Economic Dimensions of Sustainability*, moderated by **Leland Glenna** (The Pennsylvania State University), was organized as "lightning talks" introducing the issues, immediately followed by an interactive discussion between speakers and delegates. This robust and fascinating discussion of the contributions of biotechnology to a sustainable food and agricultural system explored the evolving roles of the agricultural research and development infrastructure and consumer acceptance of GE technologies.

Paul W. Heisey (USDA Economic Research Service) focused on the complementarity and changing dynamics of public and private research in his talk, *The Structure of US Agricultural and Food Research, with an Emphasis on Seed-Biotechnology Research*. The early innovations in biotechnology primarily occurred within university and public research institutions, yet research investment by the private sector has well surpassed public investment. The nature of the research conducted in the public and private sectors still remains complementary, as the more fundamental work carried out in public institutions informs the translational research often emphasized by private industry. Both in the US and globally, the seed-biotechnology industry has concentrated, resulting in fewer small and medium-sized private biotechnology companies and the dominance of larger companies. Industry concentration appears to have reduced research intensity in agricultural biotechnology, even though small and midsized companies continue to produce major innovations. Large seed-biotechnology companies are also becoming involved in farm management research, augmenting research traditionally done by the public sector.

Rick Welsh (Syracuse University) expanded the discussion of GE crops to examine the public discourse of the technology as a "social problem" in his talk, *Understanding Social Controversies over Agricultural Biotechnology*. Robust intellectual property protection for GE technologies stimulated a shift in agricultural chemical companies toward "an integrated pesticide and seed sector" that over a relatively short time has concentrated the seed industry into a few large companies. This evolution in the biotech industry has, in part, contributed to a polarized dialogue around technological changes in the food system, especially in the US. Proponents and opponents of the technology each have common viewpoints that frame the issues in support of their perspective. Concerns of GE critics include the lack of safety data for the consumer, insufficient government regulation, and potential ecological impacts. GE advocates, including policy makers, focus on the contributions of the technology to food security and environmental sustainability. The conflicting strategies of the two sides are not contributing to greater social consensus on GE technology in the food system.

William K. Hallman (Rutgers University) presented a stimulating perspective on the role of consumer perceptions in the acceptance of GE products in his talk, *Do American Consumers Want GM Food Labeling? It Depends on How You Ask the Question*. Interestingly, data show that the vast majority of Americans know little or nothing about GE foods or foods containing GE ingredients in their supermarkets. There is considerable confusion among consumers: ingredients thought to be GE-derived are often not, there is uncertainty whether foods containing GE products are currently available, and most don't know that they are consuming foods containing GE ingredients. While many consumers are uninformed about GE foods, they readily develop opinions that can influence their attitudes and decisions regarding these foods. Interestingly, purchasing decisions tend to solidify people's opinions about the nature of their food, further supporting their beliefs by adjusting information to conform to those beliefs.

Stephen Palacios (Added Value Cheskin) conducts market research to assist Fortune 500 companies with marketing strategies. In his talk, *The Limits of Science in Impacting the GMO Discourse: How Food Manufacturers and Retailers Affect Consumer Opinion*, he suggested that much of the GMO conversation has already been framed by a well-entrenched anti-GMO communications structure. The anti-GMO messages consumers get on Amazon, Google, or Netflix are indicative of a sophisticated, trend-oriented, popular culture approach that generates quick advocacy. Consumer opinions, especially those on the perceived relationships between GMOs and health, significantly impact the food industry. This becomes even more important as consumers see GMOs as "potent symbols of the ills of the American food industry." Establishing consumer trust and relevance in the context of the marketing strategies of their competitors strongly influences the decisions of industry executives. For example, the no-GMO stance that Chipotle recently adopted in marketing their products as "food with integrity" sensitizes other food companies about their position on the technology, regardless of the scientific arguments. Science might still have an opportunity to mitigate the frame set by the long-standing anti-GM campaign, but it will require carefully crafting consumer-oriented responses.

Special Presentations

At the conference banquet, delegates were addressed by **Russell C. Redding** (Pennsylvania Secretary of Agriculture), who presented *AC21—The Journey to Coexistence*. The Advisory Committee on 21st Century Agriculture (AC21), in response to Agriculture Secretary Thomas Vilsack's charge to advise the USDA on key issues facing the increasingly complex and diverse US agricultural system, focused on a set of recommendations and implementation strategies to enhance coexistence among different agricultural production systems. At luncheon on the second day of the conference, **John F. Tooker** (The Pennsylvania State University) presented *Sustainability of Genetically Engineered, Insect-Resistant Crops: A View from the Fringe*, strongly advocating for product flexibility in the marketplace. Such flexibility would allow growers to maximize economic returns by responding to local pest populations, especially through the use of IPM, rather than being limited to specific management strategies aimed at potential pest problems.

An important component of NABC conferences is the **Student Voice**, which empowers students to be active participants in the meeting. Graduate students from Penn State, University of Arkansas, Washington State University, and Iowa State University met the evening of June 2 and presented their views on the conference topics to the delegates on June 3. The students stated that greater science advocacy through effective educational programs and science communications to the public should be a priority. Basic genetics taught at early ages would help people grasp the concepts that underpin these new technologies. It also could be the time to change the focus in the discussion of GE crops from human safety, which is well documented, to potential ecological impacts that can only be accomplished through broad collaborations of scientists from different disciplines. It is also time for life scientists to work more closely with social scientists to reach out and create closer ties to the community.

Putting It All Together

The closing interactive panel session, *Putting It All Together*, moderated by **Steve Pueppke** (Michigan State University), was a stimulating conversation with two speakers (Greg Jaffe, CSPI, and William Kerr, University of Saskatchewan) and two delegates (Andy Hedgecock, DuPont Pioneer, and Tony Shelton, Cornell University) who reflected on the issues, scope, and content of the conference to synthesize a way forward in stewardship for the sustainability of GE crops.

PART II–KEYNOTE PRESENTATIONS

Thinking across Time: A 20-Year Perspective on Biotech Policy

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Memorial Day weekend, I was in search of patio furniture and stopped at the Plow and Hearth moving sale. I bought a metal sign for my patio wall that is a reproduction of an old seed packet: "Reeds Flower Seeds, To Plant a Garden is to Believe in the Future." Love it. I brought it to the register for purchase, and the college-age kid behind the counter said "Yeah, love the fake vintage sign, kind of like how Monsanto tries to sell GMOs." What? In these moments, I don't know whether to laugh or cry. This is just the latest example in which I encounter people of all shapes and sizes with strongly held but poorly informed positions on agricultural biotechnology (ag-biotech). After working on biotechnology policy for 28 years, I am still surprised by the public's reaction to the technology, and I am mostly discouraged.

How did we get here—this place of nonsensical debate over a technology that has left many Americans and others across the globe in opposition to it, despite the technology's promise to contribute significantly to solving some of the world's pressing problems? Of course, I have a thesis: the biotechnology industry did this to itself, a sort of self-inflicted wound. I readily admit that I base my thesis largely on my own experiences; I do not have peer-reviewed data to share, nor have I written an academic book on the topic. But over many years, I have had a front-row seat at many critical ag-biotech policy discussions. What I'd like to do this morning is share a very small sample of those critical moments. I ask that you suspend your own beliefs and try to see the world as I've experienced it.

I will conclude this morning with a brief discussion of a current policy controversy: the effort to achieve what has become known as "peaceful coexistence," the goal of which is finding a way forward so as to allow farmers growing various kinds of identity-preserved crops to coexist without compromising one another's livelihood through unintended

commingling of genetic material. Specifically, I will suggest that the potential re-write of ag-biotech regulations by the Animal and Plant Health Inspection Service (APHIS) of the US Department of Agriculture provides a pivotal opportunity for industry to alter its historic opposition to stringent regulation and join forces with non-biotech farmers and environmentalists, and in doing so, radically change the policy environment, mend old wounds, and rebuild trust in the technology.

Entering the Ag-Biotech Arena

I beg patience from my many old friends in the crowd, because I begin with a very brief history of my involvement with ag-biotech policy for those who do not know me. I hate to take time with a résumé recitation, but I feel it necessary because if you Google me, or if you talk with certain industry leaders, many of whom have never met me—you would likely be left with the impression that I'm an anti-biotech activist or at least someone who holds views harmful to the industry. I disagree with this characterization.

In the spring of 1987, I came to Washington straight from graduate school. Political strategist John Podesta hired me to work for Senator Patrick Leahy of Vermont. Leahy was the new chair of the Senate Committee on Agriculture, Nutrition and Forestry as well as chair of the Judiciary Committee Subcommittee on Technology and the Law. Because of these committee assignments and the Senator's interest in the emerging biotech sector—note this was just months after the birth of the Coordinated Framework for the Regulation of Biotechnology—it was determined that he needed a staff member to work full time on ag-biotech and help nurture the industry. I was that person. I got to work right away, and I helped organize a hearing on opportunities for the biotech industry and met most of the first wave of entrepreneurs setting up companies—names that are now legendary. I remember one of the first articles I helped write for Senator Leahy was a piece in the December 1987 issue of *Biotechnology* arguing that the government should make greater research investment in this sector. All was good initially.

Then the regulatory review of synthetic bovine growth hormone (BST) became an explosive issue, and I found myself center stage. An FDA staffer who was initially in charge of the BST review at FDA had become a whistle-blower, and he came to my office claiming that the agency had mishandled the scientific review. Because Senator Leahy's home state of Vermont was in an uproar about BST—it's a big dairy state as well as a big organic and sustainable agriculture state—and because of the Senator's leadership position, I found myself as the unfortunate point person in Congress, leading the congressional aspects of an investigation to ascertain whether the FDA review was adequate. As I interviewed people, reviewed documents, and requested the help of the Government Accountability Office, one problem kept emerging, and it was one that I found exceedingly difficult to overcome. That problem was finding scientists with adequate scientific credentials and expertise who had not, at one point or another in their career, been on the payroll of one of the four companies then developing BST. If a scientist had received compensation from industry, even if it was many years past, she/he did not have the necessary credibility with the public. You and I could argue that was unfair, but nevertheless, that was the reality.

The allegation that milk from BST-treated cows was unsafe was very unsettling, especially given the importance of milk in the diets of young children. And as a 28-year-old staffer, I had a great deal of authority in the BST review (remember this when you visit those young staffers on the Hill!). I had many sleepless nights worrying whether I was making the right call. Eventually, as you know, the FDA approval was upheld. But I learned a very important lesson from this experience that has informed my policy work ever since: for ag-biotech to succeed, our government must provide funding to support a cadre of independent scientific experts with no ties to industry. This is essential to establish and maintain public trust.

Risk Assessment Research

I turned this lesson into what I believe today was a big win, and that was the Biotechnology Risk Assessment Research Program that was included in the 1990 Farm Bill. This program established a competitive grants program to support the generation of new information to assist federal regulatory agencies in making science-based decisions about the effects of introducing into the environment genetically engineered organisms. For example, it has funded some of the research related to the impact of certain genetically engineered crops on the monarch butterfly population, which has been a focal point of public concern. When the program began, the statutory requirement was that 1% of whatever USDA spent on biotechnology research be devoted to risk assessment research. In other words, if NIFA and ARS combined spent $100 million on various kinds of ag-biotech research, $1 million would necessarily be spent on risk assessment research under this new program. In later years, this was raised to 3%. In 2015, $4 million will be spent through this program.

But people still don't appreciate the importance of this sort of research expenditure and see it as an implicit criticism of the industry. Let me share an example that illustrates this sentiment. In 2003 I was a new assistant professor at Tufts University running a master's/Ph.D. program called Agriculture, Food and the Environment. My first task was to organize an ag-biotech meeting on nutritional aspects, challenges, and opportunities presented by the technology. I raised the funding for the symposium and organized the speakers. I was getting a little pat on the head by my dean and was really quite proud of my achievement. But when I gave my presentation at the symposium, titled "Resolving Uncertainty through Government-Sponsored Research," I was stunned by the response. In it, I discussed the Biotechnology Risk Assessment Research Program and argued that, given the growing complexity of the products of ag-biotech, there was a need for greater public investment in risk assessment research than this mighty, but little, program could provide. To support my argument, I referenced articles in *Science* and research by the Royal Society of Canada as well as US government reports. I was very excited that a famous scientist had come to my conference and was sitting in the front row as I gave my presentation. I had admired him and the work he did from afar for many years. I won't say his name, but you all know of him. At the end of my presentation, he stood up and pointed a finger at me and said "It's people like you that cause 10,000 people a day to die of starvation." What? There I was, an assistant professor in the first six months of my

dream job, and I had put together this really big conference, initiated a very reasonable scientific discussion on identifying the gap in public sector funding, and that was how I was received! I learned that debate is not welcome. Disagreement, even reasonable questioning, is labeled as anti-biotech. This situation is unhealthy, and it is unnecessarily divisive.

Research on Resistance

I wrote an article in 1995, "Herbicide-Tolerant Plants: A Case of Science Gone Astray." It was published in the *Health and Environmental Digest*. The journal no longer exists, but the article still haunts me in my career. There was a lot of commentary on it when I was nominated to be the deputy secretary of agriculture in 2009. So what did this very controversial article say that somehow is the evidence that I'm a biotech hater? Did it say that ag-biotech should be abandoned or is evil? No, it simply laid out the case that without adequate regulation, we would likely encounter herbicide resistance and that we needed to require things like set aside or refuge acreage of non-GMO crops to slow down the likely resistance problems that would be encountered. Fast-forward 15 years, and where are we today?

I know resistance management is a topic for detailed discussion at our conference. It is widely acknowledged as a problem today, and much of what I wrote about in 1995 has become reality. I don't raise this as an "I told you so." I am saddened by the impact resistance has had on farmers and strongly believe that if the problem had been honestly confronted years ago, farmers would be in a better place today, and the ag-biotech industry would not be under such attack. Gary asked a critical question in his introduction: How do we sustain these technologies? Clearly, I am a policy scientist and don't work in a lab. Yet I have often found myself voicing the concerns of bench scientists afraid of saying anything critical about biotech. When writing this article in 1995, I spoke to countless scientists who were concerned about resistance but who did not want to be identified because they believed it would be detrimental to their careers. They were afraid of being labeled as anti-biotech. So, here is the key lesson I learned from this experience. People often argue that the anti-biotech crowd is anti-science, and in some cases that is certainly the case. But in the case of resistance management, I can say that many ag-biotech leaders were anti-science. My questioning the lack of resistance management strategies was based on science, and we would have all been better off if such questioning had been received as legitimate inquiry worthy of discussion.

One more thought on this: It is so important that we increase funding for agricultural research, and given that many of the people here are from the university sector, I'm probably not going to get a lot of disagreement in this room. I am currently co-chair of AGree, a group that launched in 2011 and is funded by some major foundations. It aims to build consensus about how to move forward in food and agricultural policy. The other co-chairs are Dan Glickman, former secretary of agriculture; Jim Mosley, former deputy secretary under President Bush; and Emmy Simmons, who was the assistant administrator at USAID under President Bush. We are bipartisan, and one of our core issues is trying to move policy makers on Capitol Hill toward greater investment in agricultural research. However, it is not just about more money, but also about how we allocate the

money. I'm hoping we prevail in our quest for more research funding and that, among other things, increased research support can be devoted to coming up with strategies to improve our risk assessment efforts.

GMO Labeling

Our second area of discussion today is labeling in trade markets. Let me begin by being clear on my position—first and foremost, I am a big advocate of transparency. The unwillingness of the industry to label for biotech has fueled the public's concern that there is something to hide. My gut tells me that if companies had chosen to label product years ago, consumers would have largely accepted biotech by now—in other words, by failing to embrace transparency the industry has itself to blame for creating this labeling storm of public criticism, referenda, and protest. That said, I have never been a supporter of mandatory GMO labeling because of the costs and complexity and because I think about food labeling in a way that has three categories: "right to know," "need to know," and "want to know."

Here again, my current-day thinking on labeling has been informed by history. Back when we were doing the organic rule-making in the late 1990s, the USDA Agricultural Marketing Service (AMS) was responsible for writing the hundreds of pages of rules that detail production and processing standards and an accreditation program to support enforcement. Interestingly, when publishing the first proposed organic rule in 1997, USDA did not include a prohibition on biotech. Why? Well, I suppose part of the reason was because of me. In writing the Organic Foods Production Act of 1990, I did not include an outright prohibition on biotech, even though the majority of existing private and state organic standards in the country at that time included such a prohibition. Yet in writing the organic law, which I hoped would stand the test of time, I wanted to leave the door open on biotech, anticipating that someday there would be an application that would be compatible with organic and helpful to the organic industry.

But the public reaction to the proposed rule was swift and powerful—a total of 275,603 public comments were received by USDA, and nearly all of them said organic should not include biotech, including my own. By the time the second proposed rule was issued (and by this time I was the AMS administrator overseeing that rule development), we put in a clear GMO prohibition. Monsanto was among the different entities that supported that GMO prohibition. The company submitted some of the most interesting and insightful commentary and stated that it was going to be very important in the marketplace to have GMO-free food products for people who wanted such products and that maintaining organic as GMO-free gave consumers that option. Fast-forward several years to the Obama administration. Because of increasing interest among consumers in non-GMO food products, several companies and certification schemes began popping up to address this market demand. Perhaps the best-known example of this is the Non-GMO Project, a private certification program. Because consumers were looking for a non-GMO label, several organic companies went to USDA and tried to get approval for a non-GMO label claim on meat and poultry products, and USDA refused to accommodate them. Officials from the Food Safety Inspection Service (FSIS) actually said to me, "How would we know if it's really not-GMO?" My answer was to suggest they walk down the hall and discuss

this concern with their colleagues at AMS, the agency that regulates the organic label. In the end, FSIS approved meat and poultry to carry the Non-GMO Project seal, but would not allow organic producers to make a similar claim. This battle continues today. Former secretary of agriculture Dan Glickman and I wrote an op-ed on this topic that ran in the *LA Times* in December 2013. It seems to me that some of the FSIS opposition must have been generated by industry, and in the end, rather than building up the organic label as the alternative in the marketplace for people concerned about GMOs, we have instead created a multitude of labels in this area and pending state law.

So where are we now? A new effort was announced this past week by my colleagues at USDA to use a process-verified program as a way to address the public interest in having a non-GMO label. I used to run the process-verified program. In it, industry members propose their standards and pay a fee to the AMS, which then verifies that they are following their own protocol and provides them with a USDA process-verified label. But that means that Greg Jaffe can come in with his standards, Neil Hoffman can come in as another company with another set of standards, then Ralph Hardy could come in as a third company with his standards, and as long as AMS can verify their processes and they pay the fee, everything is fine. I don't see how this new announcement gets us out of the labeling pickle the industry finds itself in. Bottom line—the history lesson here is that the push-back on labeling by industry has always been doomed at some level, and the greatest opportunity to elevate organic as a pathway forward was bypassed.

Coexistence

Lastly, let me turn to coexistence, the big topic on your agenda today. Currently organic and non-GMO crop farmers are losing income, customers, and seed purity when their crops test positive for small amounts of GMO because pollen is drifting from neighboring farms. Even within the universe of GMO-crop farmers, conflict is roiling. Lack of adequate regulatory safeguards has resulted in GMO crops commingling, leaving farmers vulnerable to contamination from neighbors who plant different kinds of GMO crops.

The last thing this country needs to do is to pit farmer against farmer. But I believe that America's failure to adequately regulate biotech crops has done just that. And the divisiveness on the topic of GMO crops is threatening more than crop purity in the country. The average age of American farmers is 59. We need to convince young people that agriculture is a career worth embracing. It is tough grappling with the daunting cost of land and basic farm machinery and with working long hours, all while starting families. Our young farmers depend upon companionship and support from their communities, which Wendell Berry has defined as "the mental and spiritual condition of knowing that a space is shared." That sense of shared space is threatened by the GMO crop battles, and USDA must do all it can to stop it.

With the controversy over the potential deregulation of Roundup Ready alfalfa and issuance of a draft Environmental Impact Statement in late 2009, Secretary Vilsack asked me to conduct a behind-the-scenes process at USDA to identify coexistence strategies. An internal USDA team worked with me tirelessly for many months. After we delivered our work product to the Secretary, which provided numerous potential actions, including

some identified late in President Bush's term of office but which were not pursued for one reason or another, the Secretary decided that the best way forward was to appoint a coexistence citizen advisory committee. This coexistence committee assembled warring farmers, advocates, and corporate leaders in a series of meetings to identify voluntary actions that could be taken to limit pollen drift, such as establishing buffers around GMO crops and adjusting planting times.

Everyone loves market-driven voluntary solutions such as those identified by the coexistence advisory committee and embraced by USDA because they are politically easy. But from where I sit, the obvious and lasting solution is to update our biotech regulations. Fourteen years ago, Congress recognized the need for updated authority, given advances in the science, and it passed the Plant Protection Act of 2000. In this law Congress grants USDA authority to regulate noxious weeds, defined as any plants or plant parts that directly or indirectly cause damage to the interests of agriculture. That is a broad definition and therefore a broad delegation of authority by Congress to the USDA. It is time for USDA to act on the statutory authority it was given long ago and issue fair and transparent regulations to allow all farmers to prosper. I keep waiting for full-fledged discussion of Part 340, an insider reference to the portion of APHIS biotech regulations that would be updated, if USDA chose to act. Last year USDA asked the public for ideas on how to facilitate peaceful coexistence between farmers in an era of GMO crop production. It feels like we are on a treadmill, going nowhere. The time is past for advisory committees, and general public inquiries through the Federal Register. Rather, it is time for everyone to come together and pound out a regulation that protects the ag-biotech industry and all those seeking non-GMO products.

Conclusion

Will we ever be able to discuss ag-biotech in a less contentious environment? I hope so. In the meantime, I am going to continue to straddle the debate, which is not always comfortable, no matter how necessary.

From where I stand, and with the long view of 28 years of working in this domain, there is no organization that has been as important as NABC. I am really deeply grateful to this organization. NABC has been one of the few places, if not the only place, that has consistently considered other views and created a safe space for important discussions, building bridges between various factions in the biotechnology debate. I have been part of consensus-building dialogs on biotech over the years, including a couple in the 80's and 90's led by the Keystone Center. I was part of the Pew Ag Biotech Initiative in the early 2000s. These were short-term efforts and really were stakeholder rather than research driven. The staying power of NABC is impressive. With your continued thought leadership, the ag-biotech industry may someday live up to its promise.

Speaker Profile: http://provost.gwu.edu/dr-kathleen-merrigan

Q&A

R. Connelly, Penn State: I really appreciate your insights and your historical perspectives, but I think I'm confused even more now about the labeling issue. Who will actually benefit from labeling?

Merrigan: I think that depends on what kind of labeling we are talking about, and there are many ways to answer that question. One of the interesting things in the Organic Foods Production Act of 1990 is that we included in that law a state preemption, which added a level of difficulty. At the time the industry was facing very serious interstate commerce challenges because the growth of the organic sector had now gotten to the point where there were processed foods being produced, as opposed to just fruits and vegetables. Many of these processers were obtaining ingredients from various states, and there were 43 state and private standards in the country at the time. It was really tough to think about what it would mean for all of those entities, some of them states like Washington and Texas, to give up their own standards and their own rules of production. We succeeded with our arguments, and that is the interesting part of what is going on in the labeling battle now. If there is going to be mandatory labeling—which is not anything I support—will it be accompanied by state preemption, or will there be one labeling rule of the land?

My critique on "process-verified" is that while it sounds great, you are probably just giving birth to a whole other generation of labels that will confuse the marketplace even more. So it sounds like a really cool idea, but I don't think it works. I think labeling is a small issue. I wanted to say something about trade and markets because of our agenda, but of all the things I've said, the most important one, the one that holds the greatest promise to move us forward in this very thorny debate, is really tackling regulation. In my mind, that is the sleeper issue with the greatest potential.

T. Harding, Lehigh Valley Organic Growers: Kathleen, it is always nice to agree with you. I totally agree that labeling is the wrong direction, but I would like you to expand on the issue. As we look at coexistence and now resistance on the table, how do we move from market failure to a regulation that is fair and balanced? Does that mean tolerances?

Merrigan: I think among the solutions that those of us inside the beast were working on regarding coexistence, there were very few that didn't ultimately lead to some sort of thresholds. Those are complicated discussions, and there are a lot of political maneuvering and nuances that need to be a part of that discussion, because there is a lot of suspicion. What could in some ways be an easy issue is a challenge because we are in an environment where you are either pro- or anti-biotech. There is no place for the people in-between. That is the whole point of my talk.

M. Smith, Cornell University: First, thank you for both your work and your comments. I really appreciated them. I'd like to make sure I understand clearly your comment about coexistence and organic farmers losing money. My understanding of the organic standard

was that it does require that you use a variety that is not genetically engineered and that you take reasonable measures to avoid pollen contamination. It does not have a level that says, if you find this much in your crop you lose it. I get the idea of public perception and the importance of the perception that there might have been cross-pollination and contamination, but are there actually examples of organic farmers who have not been able to market their crops as organic because of this?

Merrigan: Absolutely. This has been part of the deliberations of the coexistence advisory committee appointed by Secretary Vilsack and myself. I take responsibility and some pride in those appointments. There was a lot of suspicion of the committee members. Much concern was expressed that this was a hyped-up issue and that they wanted a lot of data and declarations from the organic interests about actual testing results and residues, and what was happening was to "screw them" in the marketplace. If I am an organic producer and you are asking me to hand over data that may torpedo my business, I may feel that some of the back-and-forth between the GMO industry and the organic industry is unreasonable, is unreasonably intrusive. Given what we know of the science today, given that I could write an article in 1995 about pollen that elicited an "Oh my God" response, couldn't we just give the benefit of the doubt to the organic producers who were presenting cases, just not giving all the names, dates, and addresses? That became a kind of third rail. It did not set up very productive dialog.

G. Jaffe, CSPI: I agree with you completely that revising Part 340 would be a great way forward. I think that we spent a lot of time on plant pest issues when the reality is we should have been spending time on resistant weeds, resistant pests, on economic issues and things like that. I think Part 340 had some good parts. It didn't address all these issues. It didn't address coexistence. I guess the question is how we can get the USDA to do this in under six or seven years. Even if they follow your suggestion, an idea I agree with, and use noxious weed regulations, by the time they do the market will already have moved forward and done whatever it is going to do. How can we get the agency to move on this quicker so it will actually have impact on this debate?

Merrigan: That's an excellent question. The USDA first pulled back a rule that had been proposed years and years ago and said they were going to go back and start over. I think that was the right thing to do, because if they had proceeded with that rule it would have obviously been easy to challenge it under the Administrative Procedures Act. So going back and starting from square one and putting in place the new proposed rule, you still have all that paperwork and all that information that may end up in your new proposed rule, but procedurally that would make a lot of sense. I have extreme confidence the civil servants at the USDA can work fast and produce a really thoughtful rule. I am calling out to you, Neil Hoffman. We worked some pretty long hours on that coexistence stuff, didn't we? And we put together some really thoughtful things. There are many great people involved, and it requires political will at the top to do the dodge-and-tackle with Congress, and with industry, to allow the civil servants to do their great work.

R. Roush, Penn State: I want to come back to this issue about the cost to organic, and not so much to your individual data. One of the issues some of us have been working on for a long time is, what's the composite? What are the trends? Where do people run into problems? I want to cite a court case about this in Australia, where everything got dumped on the table. The guy who was claiming he had found contamination and sued his neighbor was absolutely unable to prove any losses. The judge came down harder on the certifier than he did on the GM grower. Is there any advice or indication you can give us as to what the trends are? Where have the problems been? Because that is what we really need to know so as to avoid it. Not individual cases of losses, but where overall the problems are.

Merrigan: The best data and analysis are from Lynn Clarkson. Wave your hand, Lynn! He is actually the point person for the industry to collect that data. I will let him engage in that discussion and lead the discussion from the organic industries point of view. I know that there is now a move in the National Organic Standards Program to do more testing of organic crops, sporadic testing for GMO content. That will create a government-led database that might provide background data that will be helpful. What I find really interesting, as I look at this new AMS labeling scheme, is this: If a producer is in the process-verified program, it is the process that is verified. It does not deal with a residue level. It is not a threshold-based program. So there might be GM present, but it is a program that gives the organic producer a level playing field. This is where I got my start. I could have been doing any kind of policy, but I am always for the David and Goliath stories. The organic industry seemed like a little guy trying to fight his way out of a hole. We are now going to have an AMS Process-Verified label that the industry can use and put a non-GMO Process-Verified claim, on a USDA label, with no testing for threshold. But the organic guys, who have followed that rule since it went into place in 2002, are being tested. I just don't get that. I still think there are opportunities to make sure that an organic label is strong and is a really viable choice for consumers who are concerned about these things or for whatever reason want an alternative.

What Are the Major Impediments to Resistance Management for Crops in the Social Sciences and Governance?

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I am going to argue the mechanism of genetics and management theory for pesticide resistance management was well understood by about 1990–95, but 20 years later successes in delaying herbicide resistance in the field are relatively few, while there have been successes in maintaining insect resistance. After working in this area for more than 30 years, my conclusion is that the problem is not in not knowing what to do, it is in implementing the right practices. With the benefit of hindsight, I have concluded that most or all of these successes have involved some government intervention—at least to a modest level. This government involvement was proposed as early as 1989, but little or no action was taken.

I want to draw attention to Australia, where the hand of government was rather light and where intervention was quite limited. In the Australian cotton industry, innovation was driven by the growers and farmers, who then went back to the government and asked them to enforce the rules they had developed for themselves by blocking free riders from using technology without paying any of the financial and management costs to delay resistance.

In 1984 Michael Dover and Brian Croft wrote a monograph that argued that US EPA should do more to regulate pesticide resistance, because resistance would in virtually all cases lead to more environmentally risky pesticide applications and increased use. They stated that this was well within the EPA mandate, because a failure to manage resistance exacerbates the environmental impacts of pesticide use.

Also in 1984 a National Academy of Sciences meeting was held, and there was much debate about this paper. Dover and Croft had generally rejected the idea of government intervention, so demanding its involvement was an important position for them to take. Miranowski and Carlson outlined which conditions would favor resistance management at a single company level, and they concluded that for a highly profitable technology with

no potential or actual close substitutes, monitoring for resistance would be pretty easy. The monopoly permitted the company to market the technology in a way that included resistance management, and testability was such that voluntary management by growers would be economical. So if you look at the types of technologies being developed, you can talk with Charles Dickens of a "Tale of Two Monsanto Technologies." One has worked out pretty well, the other not so.

In the case of *Bt* crops, the resistance problems are relatively modest after more than 16 years of intensive use. For Roundup Ready (RR) crops, the monopoly was on the crops, technically not on the herbicide. At last count there were more than 14 weed species across the US and abroad showing resistance. Still unpublished data shows that this has resulted in varying losses to growers in excess of $99,000,000, a huge amount and actually considerably more than insect resistance costs, although even there a couple of cases beginning to show resistance. Many of the conditions that would normally favor resistance management for a single compound, as Miranowski and Carlson defined it, were met, yet there is relative success with *Bt* crops and less so far with RR crops.

I will give you a quick overview of insecticide resistance management strategies, many of which could be extrapolated to herbicide resistance and the reasons behind the strategies. I want to persuade you that this is actually pretty simple. Many rules are available for pesticide resistance management that in most cases make the determination of best practices fairly simple and straightforward. In 1989, after I had been working on this for about 10–15 years, I became aware of this and wondered why I had not figured this out sooner.

Here is a summary of my thinking since I first published it in 1989: If you look at the resistance management strategies people are discussing, you see a very short list. Should you be using high doses or low doses, or in the case of multiple compounds, should you rotate them over time, use them simultaneously as a mixture, or apply them in a mosaic, where one farmer is using one compound and his neighbor is using something else? Often overlooked in this is integrated pest management (IPM), beginning in the mid 1950s, when people realized that pesticides were never going to be a permanent solution and that the best strategy was nonchemical controls. When one technique doesn't work anymore, change your control tactics—keep the pests off balance.

The IPM strategy was based on the notion that if you could kill the heterozygotes with whatever dose you were using by controlling the length of exposure, you could delay resistance for a long time, because the heterozygotes were the most common carriers of resistance. If the initial frequency of resistance was about 10-4, which we think is pretty high, the frequency of resistant homozygotes would be small. Some populations wouldn't even have resistance from homozygotes. So if you kill all of them, you basically stop resistance in its tracks. But the strategy was more complicated than this. It depended on having a very low initial frequency of resistance. The mortality had to be high—greater than 95%—and even across the range of life stages. You might be able to kill neonate cotton boll larvae when they are barely visible, but by the time they have grown into "snakes," as we sometimes call them, once they are about an inch long, it is virtually impossible to kill them.

You also must have effective refuges that are not affected by insects migrating back and mixing with each other. For weeds we don't really have refuges in the usual sense. The strategy there is using a seed bank where some weed seeds stay in the crop for a year or two without germinating and come back out later. The basic details of all this were worked out by Tabashnik and Croft in a 1982 paper that really pulled all the analyses together in one place. Most resistance that poses a real problem is due to single major genes that give you three genotypes—septal homozygotes, heterozygotes, and resistant homozygotes. If you transform the mortality on this scale of a low dose you can see the difference between the three different genotypes. Tabashnik and Croft showed that if you increase the dose and kill everything, you can delay resistance indefinitely, but only if you have strong migration of septal homozygotes to mate with these individuals and convert their offspring heterozygotes that get killed at the dose used. In absence of migration, the time to resistance would get ever shorter, because obviously the only possible survivors would be the ones that carry both genes.

The next strategy was to see what would happen if more than one compound was used. One of the most famous of these strategies was adopted in Australia in the 1980s to try to manage resistance to pyrethrin in cotton bollworms. Australia already had had problems with DDT resistance, including spectacular failures in a new cotton growing area in North Australia, where the crop failed and farmers just walked away from the fields. We know that one of the major mechanisms of resistance to DDT is an altered nerve channel that provides resistance to pyrethroids as well. The cotton growers were very concerned about this. So they divided their cropping season into three periods, early, mid, and late, and they rotated the pesticides over time, trying to take advantage of the different susceptibilities of the beneficial species. And even though Endosulfan is considered to be a fairly noxious pesticide in many ways, it didn't have the effect of blowing out secondary pests in Australia, as did other pesticides. So they went with pyrethrin in the early season when they most needed to protect the crop and finished with organophosphates in the late season, all of which had different target sites.

One of the most interesting aspects of this strategy is that we went back to it years later to analyze what would have happened if we had taken other measures, and it looked like it bought them at least six or seven years of use of pyrethroids compared to what would have happened if they had used a laissez-faire approach. It is important to note that this strategy was adopted through a soft approach to regulation. The regulations were put on the label of pesticides, so pyrethrins were used in the middle of the season and beyond that enforcement was done not by a broad government edict but by other, more subtle actions. In Queensland, for example, where all the pesticides were being applied by air, if an aerial applicator applied a pesticide outside the target area, he risked losing his applicator license. It was a minimalist regulation that required people to participate, and a lot of compliance was voluntary, and successfully so.

Why did this work? I did some experiments with mosquitos, where I took mosquito populations that were carrying pyrethrin or DDT resistance—two different genes, two different chromosomes. I split the population and in every generation I set 10% of the

mosquitos aside. Of the others I treated half with DDT and half with pyrethrin and found an approximately twofold delay of resistance. Why should this happen? You can do this as a thought experiment: If you had a pesticide that was effective, but a single treatment would cause resistance to everything in the population, you would lose that pesticide immediately. Now let us say that you use two pesticides at the same time, so half of the population gets treated with either one or the other. Depending on dominance relationships, somewhere between 25–75% of the population will be resistant. If you had used just the first pesticide, you would at least have the second pesticide to use in the second year, giving you roughly a twofold advantage—a latent resistance. Based on this experiment it is obvious that allowing people to apply pesticides any way they want in neighboring fields must be the worst possible strategy. This is essentially what happened in Australia and in other countries.

Dave Pree in Canada has observed problems with oriental fruit moth developing resistance to various pesticides. Even though he started out in the rescue stage with very high survival from both types of insecticides, he persuaded growers to go on a rotational scheme, and over time resistance actually declined: Even though he started out with a real problem, he was able to back it off by discouraging growers from using the pesticides in neighboring orchards at the same time.

As a next strategy there are several different options. If you are prepared to accept that a rotational scheme is better than just a laissez-faire approach, what is required for mixtures to work? Once again you must have low initial gene frequency and no cross-resistance. Resistance to at least one of the two toxins needs to be somewhat recessive, and you need to get redundant killing of the septal homozygotes and maintain refuges. In order to make this work, you must be able to control the susceptible twice, because if it was susceptible to one pesticide you need to take out whatever resistant carriers might be on the second locus.

Hugh Comins in Australia and Fred Gould in North Carolina independently called this "redundant killing." The same principle works for pyramiding GM traits for *Bt* as it would for pesticides. This highlights what people have thought for a long time—that pesticides have to have equal decay rates—but that that is actually wrong. Even if they decay together over time, rare cross-resistance to one of them may occur. So the equal decay rate is less important than an abrupt drop-off of the septal homozygotes. If they are exposed to one pesticide, you have to expose them to other pesticides with extreme prejudice—you have to make sure they die.

Seen from a different perspective, if you assume the model of one locus per pesticide, then these are septal homozygotes with some resistance to both treatments. Individuals carrying both resistance genes are extremely rare. However, once you actually do the experiments you start getting survival far sooner than you expect. You get resistant individuals surviving. That is what makes the strategy fall apart. The key is redundant killing to make sure that if any individuals are carrying one genotype, they are killed by both pesticides. Resistance really starts to evolve here, and the model shows that if the residues decay or decay unequally to the point insects aren't killed, you don't really see much of an advantage for pyramiding genes or mixing compounds.

In the example of the cotton bollworms, using the same assumptions for a pyramid as for sequential use you see that you need greater than 95% mortality to get a high level of delayed resistance. The advantage of this in terms of designing a useful plant is that if you create a plant that has one gene and another plant that has another gene, you should be able to put insects on them and collect them every day. You don't have to wait until you get resistance. You can collect insects—thousands of them—on day 1, put them on the plants that incorporate the toxins, and it better kill a lot more than 95% of the insects to show that it is effective.

This is where Tony Shelton, Cornell University, enters the picture. We did these experiments with coddling moths Tony had collected in various places around the US that were resistant to one of two different *Bt* toxins. One of the toxins was identical to the one Monsanto used in cotton. We then looked at what happens if you have a mosaic strategy where half the plants get one and half the plants get the other. After 12 generations, the coddling moths were obliterating the resistant plants if they were carrying only one gene. But if we pyramided them, we went through 24 generations before we got bored and had to move on to the next thing.

So what about the herbicide-tolerant crops introduced in 1997? There was little widespread adoption of resistance management tactics as an entomologist would know them, and there was no government regulation. In Australia we did something different, because the first case of any herbicide-resistant weed in the world was actually discovered in Australia by my office neighbors, Chris Kastner and Chris Preston. An extension agent in New South Wales reported an orchard with annual rye grass that was surviving multiple applications of Roundup, and he thought something was wrong there. So he sent the seeds down to Steve Powles, Australia's weed expert. Steve tested them and walked me out to the greenhouse one day, and it was astonishing. He had dozens of susceptible plants from different locations, all sprayed with a field grade of Roundup, and several plants were dying, but the plants from that orchard were still growing.

I had been asked to serve on an advisory committee on genetic engineering and manipulation in Australia, and we started developing best practice guidelines. There were five or six steps, but the key argument was that if you are going to use herbicide tolerance, whether GM or conventional, don't include the same herbicide resistance in two different crops if you intend to use rotation. As the second company coming on the scene, you were expected to figure out the alternative to the one already in use by the first company, or at least come up with a compelling resistance management strategy, such as the traditional strategies of IPM, cleaning the equipment, etc.

RR canola was approved by the Australian federal government in 2003 but banned by states until 2008. So from 2003 to 2008 there was no GM canola grown in Australia. From 2008 until 2013 we conducted a five-year study in locations where RR canola was grown and areas of Australia where there was already widespread resistance to Roundup of annual rye grass from conventional cropping. A number of the fields we looked at had actually had RR canola planted twice, in year 1 and again in year 4. In years 2 and 5 we went through all those areas and compared the various control plots and monitored some

68 fields overall. There was no relationship between the use of RR canola and the increases in resistance in rye grass. One of the primary reasons for one of our recommendations—written by Monsanto in 1998 even though not finally put into practice until 2008—was that if you grew a RR crop you shouldn't use Roundup on the same field the following year. That would tend to stabilize and intensify resistance. This was effective in Australia.

Why did this work? Chris Preston was working on this, and by about 2000 he had found not 1 but 44 populations of Roundup-resistant rye grass in Australia in an area where Roundup had been used extensively for 15 to 20 years. This didn't have anything to do with GM. It was conventional use, since in most of Australia Roundup is applied to a bare field, after which farmers do direct drilling to avoid winter runoff and to retain moisture. The number of years of Roundup application is more important than the number of times per year. Resistance was worse in cases where no other herbicides were used. That, however, was usually correlated to farmers rotating the herbicides rather than to anything else. Another factor arose in areas with little to no tillage, where some farmers then decided to till the crop in order to kill the resistant weeds. My model showed that that tilling probably wasn't the cause, because you couldn't kill more than 95% of weeds that way. It showed that it was much more likely that tillage kept putting some seed back in the seed bank every year so selection density was lower. Tillage created a refuge.

Chris Preston did some really interesting experiments. He put Roundup-resistant and susceptible rye grass in petri dishes and put Roundup on the leaves. When we put them on a photographic plate, we saw that in the susceptible ones the Roundup quickly reached the roots. In the resistant ones it stayed right where you applied it. There must be a transport mechanism, but we didn't know exactly what it was. However, not knowing did not matter for developing a strategy. We found that the resistance was three to seven times lower. At that point I found that when I ran the data for Roundup through the model, it successfully predicted how fast resistance was evolving to other pesticides. But I couldn't get resistance to evolve fast enough for Roundup, and we finally realized that we had included fitness in the model, and there must be a spectacular fitness to this to cause this delay.

Chris took different populations of rye grass, some of them plants that were resistant to Roundup but with a small susceptibility, or he hybridized to make sure there was some susceptibility. The percentage of survival dropped from 50% to 0 in a spectacularly rapidly fashion over a period of just four generations. Even when he did this in different areas, it seemed to be most enhanced when there was high weed density. One of my hobbies has been to collect data on fitness cost, and this was the biggest one I had ever seen. It is spectacular. Usually resistance hangs on for a long time, but for Roundup it was spectacular. We concluded that the fitness level was so high without providing a great fitness advantage because people didn't use Roundup year in and year out. The conclusion we came to, one consistent with observations in the field, was that as long as you used Roundup at least one year out of every three you could pretty much hold the resistance at bay. It wasn't increasing at a fast rate. We also realized that we had to stop farmers from doing another Roundup application if the weeds got too large. As with our experience with insects, once the plants get bigger their sensitivity decreases and you are more likely to discriminate between the ones that are barely susceptible and the ones that are really resistant.

In the US things were different. Chris and I talked to people at Monsanto but were unable to persuade them of the wisdom of this practice. One of our arguments was that if they accepted this model, they would not produce any RR corn at all. You would reduce use of RR to either soybeans or cotton and you could back off on the selection intensity. Even if you created RR corn, you could argue that people should use alternative herbicides in different years to avoid a steady diet of Roundup year after year. I personally believe that the reason Roundup resistance started showing up so quickly in American weeds was not because of RR crops per se, but because of selection long before RR became available, just as in Australia. It was the RR crops in light of conventional selection that made resistance become a problem much more rapidly. We have been looking at this problem now from an economic standpoint and we have realized that if you look at the economics, RR for corn isn't nearly as valuable as for soybean or cotton. One indicator of that is that the RR trait in corn was adopted much more slowly than in the other crops.

Now let us get back to insecticide resistance management for GM crops, because there success has been better. Over the last 16 years we have had some cases where resistance to *Bt* has evolved. They include cases such as armyworm in Puerto Rico, and now there is strong evidence of it as well in large areas of Brazil. Maize stem borer in South Africa. Pink bollworm in India. There is some controversy about whether this was first documented by Timothy J. Dennehy, who was then working for Monsanto. Monsanto believed it even if some other scientists didn't. Another one is that *Bt* corn resistant to corn rootworm fails test number 1, that two genes independently don't give you anywhere near the control. This is a train wreck. Very predictably we were going to get resistance to that. And there is also the indication of increased frequency of insect resistance in various countries, but probably not in the US.

My friend Bruce Tabashnik has worked on this for a long time, and he argued in 2013 that field outcomes support the theoretical predictions that the factors delaying resistance include recessive inheritance to resistance, low initial gene frequency of resistance alleles, abundant refuges, and use of two types of *Bt* crops. This is exactly what Tony Shelton and I modeled in plants in the early 1990s. Those were the key factors in delaying resistance.

So what went wrong in these cases of control failure? They seem to be largely due to lack of any kind of government intervention in one way or another. There is an absence of structured refuges and probably low efficacy of toxins. That is exactly what was predicted to go wrong. I would argue that one of the most volatile cases in the world for resistance to evolve is cotton bollworms in Australia. A lot of cropping areas were grown with irrigation, and no sensible farmer would waste his money on irrigating anything other than cotton. We had data that showed that sometimes in the Australian system naturally occurring refuge crops were less than 5%, so we really drove the growers hard to use refuges.

Successful management strategies include large refuges and high expression of the toxins relative to the pest. Government intervention, in both the US and Australia, led to the use of refuges. Here is an example of a refuge crop. This not-Photoshopped shot

shows a real cotton crop in Queensland, both the *Bt* crop and a refuge. It shows you why, in the absence of *Bt* crops, cotton was sprayed 15–18 times a year. In Australia we have been able to keep that system going.

What happened to these two technologies? Just look at the corporate cultures driving this. At Monsanto there were Pam Marrone, who by now has set up her own company, Steve Simms, and Terry Stone. They decided internally at Monsanto to establish their own culture. They selected the first strain that was *Bt* resistant and proved to management that you couldn't ignore this possibility. They had to be taken seriously. What happened on the other side? When it came to RR crops, there was a strong view within Monsanto that resistance was nearly impossible. They used an herbicide that had been in use for around 25 years without ever failing—a much better record than any other herbicide on the market, so they might be forgiven for thinking that nothing could ever go wrong. But I don't think any entomologist would have been so bold as to say in the 1990s that resistance wasn't possible. So there were two different cultures in one company back then.

This is the backdrop to herbicide resistance. While resistance has a solid research history in entomology, here the potential problem was nearly undetectable. It was a curiosity, not really a threat to agriculture. They didn't take it seriously.

One of the key points to make here is that refuges for two *Bt* crops were essentially mandated in both the US and Australia. The USDA and the EPA were intensely lobbied to protect *Bt* on the grounds that it was a public good. In particular that resistance to *Bt* would have adverse effects on organic agriculture. Strictly speaking, it probably wouldn't have made a difference for organic agriculture, because the pests that were targeted by *Bt* in these crops were not affected by the use of *Bt* in organic culture or anywhere else. Cotton bollworms go inside of the boll. Corn borers go inside the stalk. You can't really control them with *Bt* sprays. So it wouldn't have made any difference, but it was a nice argument at the time.

Why wasn't this done for Roundup? Arguably one of the safest herbicides ever developed, so why wasn't it also seen as a public good? Another one of my key points is that in Australia the cotton growers are very concerned about resistance and the history of resistance to insecticides such as *Bt*, and they encouraged the government to adopt public sector recommendations. I remember very well when I was the one person in the room who wasn't affiliated with the Australian government, Australian growers, or Monsanto. We presented our case for a strategy in Australia to the growers, and Monsanto presented their case. At the end one of the Australian growers, the committee chair, told us that they were not interested in a short-term solution and that they were going to use our strategy in Australia, not Monsanto's. They developed and endorsed a resistance management

strategy which they then asked the government to enshrine in regulation. They took the strategy to the pesticide regulatory authority and to a gene mapping organization looking after genetically modified crops and said, this is what we would like to have you put in the rules. Soft regulation, driven by people who have an interest in going to the government, not a heavy-handed EPA crushing everybody, as seems to be the perception of the US regulation. It meant educating the growers and working from the bottom up.

I hope I have shown you that even in early cases such as rotation of insecticides in Australia, government intervention usually seems to be needed to preserve refuges and develop resistance management strategies. It has been successful for insecticide resistance management strategies but not for RR crops, and there is a vastly different outcome as a result. I think we need to try to revisit the notion of soft government intervention. At least some government intervention is required to make these things work, and maybe we can come up with a common denominator about the form that takes.

Speaker Profile: http://agsci.psu.edu/dean/biography

Q&A

A. Read, Penn State: What is it is about Australian cotton growers that make them more interested in the long term and less discounting of future developments than American growers?

Roush: Part of this is that Australian cotton growers are extremely well educated and savvy. I gave a talk in 1994, at the dawn of introducing *Bt* cotton to Australia, to cotton growers. It was at a big room at a casino, which I think is a great metaphor for pest resistance management. Ninety-five percent of Australia's cotton growers were represented, and you could hear a pin drop in the room. I gave similar talks in Mississippi and Texas, and 25–30 surly guys turned up. The atmosphere was completely different when I talked to people in Mississippi than when I talked about the same thing in Australia. Part of it was the sophistication of the growers which, of course, not all growers have. For example, some great strategies were developed to stop ticks from evolving resistance to Acaracide in Australia. They failed miserably, because cattlemen in Australia were cowboys and didn't pay attention to the rules and didn't think it would affect them. But when DDT was banned in Australia, they were left without alternative treatments for a while, and they realized that when you live on the edge of the earth you can't expect a new insecticide or herbicide to be developed just to save your 2% of the market. The same applies to herbicide resistance. They are taking herbicide resistance more seriously than elsewhere in the world because they know they are on their own. This helped drive them to be a bit more inventive.

G. Thompson, Penn State: Following up quickly, are there any differences in the relationships between the growers and the government?

Roush: There is not such a combative relationship. The government regulators keep a very low profile. They don't attend a lot of meetings.They turn up at the last minute and listen. It is much less adversarial. The growers, fully aware that they are living on the edge of the earth, have a much greater sense of personal responsibility to make sure the industry survives. Nobody else is going to come help them.

S. Fleischer, Penn State: I want you to elaborate on this. Why didn't they develop Roundup as an herbicide? Did they have the legal authority?

Roush: They questioned their legal authority, but I would say if you have the legal authority to grow *Bt* crops, why can't you use Roundup? I think it was the opposite. We were under intense pressure to do something about this new technology, and *Bt* crops seemed to be a threat to organic growers. While I doubt that that was ever the case, it made a good argument. It got lots of people engaged in the debate and stirred up. I think the agricultural community felt political pressure to do something, but just a little, not too much. I think that is how we got into trouble with some other pests since we have some existing regulation and there is a sense of we have been there, done that. We have done something and over the last few years we have marketed first and disagreed later. In some ways things are not as neat and tidy or as rigorous as they were in 2000. Basically they said Roundup is a chemical, and who is going to defend it even though it is a chemical that is so safe we will let people buy it in a store and take it home and spread it on their plants. There are few other herbicides you can do that with.

T. Harding, Lehigh Valley Organic Growers: I am curious about your recommendation for organic growers. Looking at resistance, you put some very good models up there. Many of those are things we advocate for throughout our industry, but this is not just an organic problem. This is a non-GMO problem and there is a whole industry affected by this. What do you recommend we do from the perspective of moving forward with coexistence, resistance, and meeting market demand?

Roush: I almost think the resistance can be handled as a separate issue. Organic growers can have problems with non-crops, like broccoli and cauliflower. In fact, Tony Shelton has worked on *Bt* resistance for organic growers who have similar problems in crops. We worked a lot on this issue of coexistence in Australia, and that is why I am curious about where the areas are that have run afoul of each other. We used herbicide resistance as a marker and studied first non-transgenic herbicide resistance and then Roundup resistance over a period of ten years. We looked at pollen flow for canola in Australia and found that basically we re-proved what canola growers already knew—that most pollination in canola occurs within the plant or adjacent plants and that the pollen flow was really a small factor when looking at more distance. In terms of coexistence, if people would come to some agreement on a threshold of what would be allowable, e.g., if it was less than 10%, we could tell them that 100 meters is far enough. We have data from about 100 fields in Australia that show that if you are 100 meters away, your level of pollen flow would be so low that you can't detect it by any means other than what we were doing—planting out a

vast number of seeds and measuring how many plants were transgenic. So if you allowed some kind of a threshold for that mixture, then there would be many opportunities for coexistence. The other issue in Australia is that long-distance pollination seemed to be primarily from bees, most of which were feral, displacing native bees. We didn't have too much argument from ecologists when we said that if we could identify some organic canola growers, could we just go around the neighborhood, find where the feral bees are living, haul out the eucalyptus trees, and knock out their colonies? We probably would be doing some good for the local native bees. We could adopt strategies like that. In other crops, like corn, pollen flow is still quite limited, but it is a matter of coming up with adequate distances between the fields. There is still a remote possibility that something can move long distances, so you have to have a threshold. The threshold could be below the limit of detection by any kind of routine testing currently done, ELISA etc. The way we did these pollen flow studies was to collect pounds worth of seed from canola fields. In the first round we collected and planted 58,000,000 seeds from about 50 canola fields that were upwind or downwind from 20 herbicide-resistant canola fields and planted out in fields, looking for those scattered survivors that would survive two or three applications of herbicide. That was the only way you could do it. The detection was so low that you couldn't do that by any other means. I think the main issue to be addressed is that if you really want to allow everybody the freedom to farm the way they want to, you can't have a dotted line that says no contamination at all, something which you probably can't measure anyhow. If there was a reasonable threshold value, you could work out the necessary isolation distance.

K. Merrigan, George Washington University: It is really an interesting question why EPA dealt with *Bt* but not glyphosate, and one of the things I want to share is that industry did admit that there were resistance problems with *Bt*, but that with thousands of different *Bt* strains they could always find a different one to use. But they admitted that there was a problem with glyphosate, which gave regulators a foot up. Then part of the conversation revolved around the question of if there really is such an endless diversity of *Bt* that you can go back to the shelf if the first product fails and use another one.

Roush: I agree. I once wrote a letter to EPA that I distributed to lots of people, opposing the first registration case ever performed for *Bt* corn. It was an application by Syngenta, and what really set me off was that the application proposed that if resistance to *Bt* developed they would just use another toxin. I saw red with that application. It was one where the expression in kernels was very low. For some reason they thought they could get it through the regulatory system more easily with no expression in kernels. They used a pollen promoter with fairly high expression in pollen, and this was when tests by John Losey at Cornell showed some marginal impact on monarch butterflies. He showed that only for this event, not any of the others. I opposed this application vigorously on grounds of the long history of insecticide resistance. When resistance first started occurring to insecticides, people said, don't worry, we'll find others. Curiously enough, I worked in Mississippi in an entomology program called the Clay Wild Entomology Building, and Clay Wild famously announced at the Southern Branch Meeting of the Entomological Society of America in the 1950s that taxonomists should collect all the houseflies they

were ever going to need because they were going to be driven extinct by DDT. I worked in a building with his name on it with 80 different resistances found in house flies. So when people came forward to say we don't need to worry about this, we'll come up with more *Bt* toxins, I said this was not good on the basis of history and that this application should be sent back and blocked until they came up with something more sensible. At least there was some admission of it then, but there was a perception—not just in Monsanto but I suspect among a lot of herbicide specialists—that resistance to Roundup was impossible or nearly so, when in fact it was all fluff.

T. Redick, council to the Soybean Board: At National Corn Growers we have actually looked at resistance, particularly in weeds, since there are lots of problems with that. You mentioned that you had a double stack that seemed to work a little better. We now have octostacks, and the whole soybean pipeline is quite stacked for different traits. Now that Roundup is generic, we can actually stack it for free with LL and everything else. We also have all these new forms of herbicide-resistant strains that are getting approved by the USDA after long hauls. What role do you see for these stacks to work their way into your strategies? Can you give us a little better mosaic for using these stacks, because it's going to get complicated?

Roush: The advantage with *Bt* crops was that we could control expression and dose. When some of the early *Bt*'s came out, we had mass expression, and I tested a bunch of *Bt* potato plants for algae. They had a whole range of expression levels, only some of which controlled the Colorado potato beetles successfully. The modeling showed that if you really wanted to make this work well, you had to make sure that you picked the transformation events that have good expression. For a long time people said they have to have equal decay, but that is not correct. It can either not decay all season long or decay within days, so you don't have continued emergence from the soil with insects or weeds being exposed evenly over time. The use of lower and lower doses might mean that you eventually get resistance in 20, 30, 40%. Growers often answer my question about insecticide resistance saying that they use a mixture of insecticides. When I ask them how often they find no surviving insects after spraying, they can't give me a single instance. I have to tell them that in that case it really doesn't work well. Because some of the surviving insects will be carriers of resistance. In *Bt* plants we could get pretty good expression in almost all of the seeds. But that peters off after a little while. I have been haranguing Monsanto for years to boost the expression in the first round, because it has always been weak, and they have done better since. The problem with herbicides though is that you can't control the decay. It is just like any other pesticide. So if you are going to use two herbicides in a stack, they must have very short decay periods. You might be able to get away with something like Roundup and some other herbicide that, like Roundup, has a very short decay period. Growers will spray millions of acres and plant the crop the next day. You might be able to get away with that with Roundup because almost as soon as it hits the ground it is no longer active against the weeds, but you would have to find a mixing partner that would work the same. Unfortunately I can show you data for the so-called double knockout, where mixtures with Roundup were used one right after the

other and still the level of control was not high enough. You couldn't get 95% each, so there was no benefit from doing the double knockout. So I am skeptical about these. If people are going to put multiple herbicide tolerances in crops, they should really look back at using the herbicides in rotation. They should consider that a viable option. They don't have to use Roundup all the time. Go assess what the weed problem is and pick the best herbicide for the spectrum of current weeds among the suites of tolerance that your plants have. But don't rely on mixture strategies.

M. Horack, Monsanto: Thank you very much for your talk. Please elaborate on the economic and sociological drivers for Australian cotton growers and how they are changing their practice to manage resistance.

Roush: Part of the reason why *Bt* cotton was introduced so early in Australia was that Australian cotton growers were being deluged by complaints from the public because pesticide residues were found in various places. With the salt ban, even though it was seen by the growers and pest managers as being a reasonably good option in terms of not causing pest outbreaks in cotton crops, to their great frustration salt kept turning up in some of the rivers in the area. They eventually contracted with a chemist from Sydney who determined that it wasn't runoff, as people thought, it was condensation. The rivers are cold, some of the salt gets airborne and condenses in the rivers. They barricaded the rivers to keep out runoff and they still were getting it, and it drove them mad. So Jim Peacock came along, and as soon as *Bt* technology looked like it was in the wings, he went to Monsanto and told them they had fantastic varieties, varieties which would often beat everybody else's varieties around the world in trials. He suggested using these Australian varieties for genetic modification because they wanted to get *Bt* into Australia as soon as possible. *Bt* cotton was introduced in Australia six months after it was introduced in Texas and Mississippi. It was largely driven by Jim Peacock going out and doing that deal with Monsanto. The Australian cotton industry, to its credit, decided about 1985 that it was going to try to do its best to stay out of the headlines and become not newsworthy at all, ever. And they tried to address all their environmental issues. When *Bt* cotton was first introduced, thanks to the modeling and work I did on the single genes and the low refuges, we restricted *Bt* cotton to no more than 3% of the area until the second generation of *Bt* cotton became available. The growers planted next to towns and next to streams, so they provided a buffer for the rest of the cotton operations that used *Bt* cotton. When Roundup Ready cotton came along, they were also keen to use it, because if they planted a Roundup Ready cotton crop, they could control the weeds with one spraying of Roundup and some touch-up with other sprays instead of using four or five herbicides, many of which have dubious environmental impacts. And they were keen to make sure they didn't have Roundup-resistant problems in cotton cropping and they linked with southern grain growers to develop similar strategies.

Coexistence of Biotech, Organic, and Conventional Crops: Facts, Issues, and a Path Forward

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This paper will discuss some of the many issues surrounding coexistence. First, I want to give some background on the Center for Science in Public Interest (CSPI) and its biotechnology project. Then, I will introduce the concept of coexistence and discuss the Secretary of Agriculture's Advisory Committee on Biotechnology and 21st Century Agriculture (AC21), which spent two years clarifying and defining many of the issues surrounding coexistence. Lastly, I will discuss some of the USDA activities that have occurred since the AC21's report was released, and end with some suggestions on the path forward for this controversial issue.

Background on CSPI and its Biotechnology Project

CSPI is a food and nutrition consumer organization founded more than 40 years ago by Michael Jacobsen and two other scientists who wanted to educate consumers and advocate for them using science. CSPI is often called the "food police" because it informs people about the food they eat and, typically, why it is good or bad. In general, CSPI wants people to understand the relationships among the food they eat, their overall diet, and their health. CSPI publishes a newsletter, *Nutrition Action Healthletter*, ten times a year and distributes it to about 850,000 subscribers in the US and Canada. It provides useful health and nutrition information, ranks products, and provides recipes.

To maintain its independence, CSPI is supported primarily by subscribers to *Nutrition Action Healthletter*, who pay $10–20 a year for a subscription, and by donations; some people give us $10 and some give us $1,000. CSPI does not—nor has it ever—taken funding from industry or the federal government. This ensures that the organization can remain a trusted source for food and nutrition issues with no actual or perceived conflict of interest. CSPI does receive a small amount of funding from philanthropic foundations, but not from foundations that are directly linked to a corporation.

The biotechnology project was started 14 years ago when I began at CSPI, and we have made statements about biotechnology based on the best science. CSPI's position is that the biotech crops currently on the market in the US are safe to eat and provide some benefits. However, genetically engineered (GE) crops need to be assessed on a case-by-case basis, and the regulatory system in the US needs improvement. CSPI also believes that GE crops can be used in a sustainable manner, but unfortunately that does not always happen. As Kathleen Merrigan mentioned, CSPI is neither a proponent nor an opponent of the technology. While CSPI does assert that the current crops are safe, they must be used properly with appropriate oversight. Those positions are shared by few other organizations.

Introduction to Coexistence

What is coexistence? The AC21 report on coexistence issues defines it as the concurrent cultivation of conventional, organic, identity-preserved (IP), and GE crops, consistent with underlying consumer preferences and farmer choices. The definition embodies the idea that consumers should be able to get the products they want. In other words:

- Can different production methods get along?
- Can farmers grow what they want?
- Can consumers get what they want?

There is, unfortunately, a very polarizing debate about biotech crops. In the context of coexistence, some people talk about "unintended presence," others about "contamination"; that language makes it clear that there are very different perceptions about the topic.

Here are some background facts: First, coexistence is not new, nor did it start with biotech crops. Scientists, biologists, and farmers have long been trying to separate crops for various reasons. Rapeseed is a good example: there is edible rapeseed and rapeseed for industrial purposes, and the two varieties need to be separated. Another example is corn: blue corn vs. white corn vs. yellow corn. A product made with blue corn shouldn't contain too many white or yellow corn kernels. The farmer needs to keep them separate. So the idea that coexistence was not an issue in the past or would not exist without biotech is just not true.

The second important fact about coexistence is that it only involves relationships between legal products. Many people think that a good example of a coexistence problem is either Starlink or LL rice—crops that were not approved for entry into the food supply but showed up anyway. However, coexistence is about individual farmers being able to grow crops that are legally approved, not about accidental contamination by nonapproved products. While that may have the same impact, coexistence specifically refers to a product that has been found to be safe and that is legally sold.

The third important fact about coexistence is that coexistence between different varieties of a crop depends on the crop's biology. Coexistence can't be discussed in general terms, but must be considered with a specific crop in mind. Coexistence issues for corn are very different from coexistence issues for soybeans because they have different methods of reproduction, and their pollen has different characteristics. Those crops also have different

ways of being farmed, harvested, and sold. These nuances and details cannot be avoided in the discussion of coexistence.

Finally, coexistence is not just about biotech vs. organic, although it is frequently portrayed that way. The reality is, as Kathleen Merrigan mentioned, there are nonbiotech and biotech coexistence issues (e.g., in cases of export to the European market) and biotech-biotech coexistence issues around functional traits, such as engineered corn that produces the amylase enzyme. It is important to understand that this is not just a singular discussion between only two forms of production but is, in fact, multilayered.

The coexistence issue between biotech crops and conventional or organic crops, however, is polarized and controversial. At a recent coexistence workshop sponsored by USDA at North Carolina State University, Secretary Vilsack said, "Unfortunately both sides have failed to truly speak about these issues in a way that advances the conversation. It is confusing. It does little to advance the interest of either side or it negatively impacts consumer confidence." Having met Secretary Vilsack a couple of times and read a lot about what he does, I know he doesn't like to say negative things about agriculture. He wants to be positive about US agriculture and seems to have become frustrated by this topic and by the surrounding debate.

Here are two examples taken from comments that the USDA received during the public comment period to illustrate just how polarized the debate is. One is from BIO, the industry trade association, which states, "Ultimately, growers seeking a premium from IP crops are responsible for implementing the necessary practices to preserve them." That comment sounds like "It is not my problem, it is their problem." On the other hand, Food and Water Watch states this: "Those who patent and promote and profit from GE crops should be responsible for preventing contamination and covering damages in cases where prevention fails. Any strategy for coexistence between all types of agriculture must be based on a strong regime of liability for contamination being designed by patent holders." This is an example of the viewpoint that one farmer or another is totally or solely responsible.

USDA's AC21 and Its Report on Coexistence

Secretary Vilsack established AC21 in 2011 to deal specifically with coexistence when he announced that GE alfalfa was finally being deregulated after USDA had completed its environmental impact statement. The 23 committee members represent a cross section of stakeholders; one of AC21's strengths was that about one-third of the members are farmers who farm organic, IP, non-GE conventional, and/or biotech. The committee was given the following primary charge: Determine which compensation mechanism might be appropriate to deal with economic losses of farmers whose income was reduced by unintended presence of GE material. In addition, there were several subcharges:

1. What would be required to implement that mechanism?
2. What would be the eligibility standards? Would there be a tolerance or threshold for compensating for the loss?
3. Only after we got through both of these were we also to look at actions appropri-

ate to bolster or facilitate coexistence among different agricultural production systems in the US.

The committee was somewhat frustrated by the primary charge because the committee wanted to suggest actions first, before getting to the details of implementing the mechanism and determining eligibility standards when the actions did not work. Actions that could prevent losses were, for committee members, essential. However, Secretary Vilsack was very specific that he did not want us to focus solely on the third subcharge, but instead to address the economic issues first.

In an attempt to achieve a consensus, the committee had many plenary sessions and work group calls, and we listened to comments from the public. Instead of insisting that the committee reach consensus, the Secretary wanted recommendations accepted by a majority of the committee. That meant that the committee did not necessarily have to accept the lowest common denominator. Any group can always get consensus about *something*, even if it is just that the sun will come out tomorrow morning—such consensus is quite useless.

The key areas the AC21discussed are important because they identify and elaborate on many of the issues surrounding coexistence and the viewpoints of different stakeholders.

- The first question the committee asked was whether there was an actual problem requiring a policy solution. There was a lot of controversy on whether data was available demonstrating losses that needed to be compensated. On this issue, the committee did not come to a consensus. Finding useful data on economic losses was problematic, in part because those who are experiencing economic losses don't want to let their customers know that they cannot meet the standards that they are supposed to meet. There is a fear that if this became known, the customers would not want to contract with them anymore, so they treat this information as proprietary. The AC21 understood the reasons why it would be hard to get this data, but the lack of data does not mean there are not farmers who have economic losses due to the inadvertent presence of GE material.
- A second issue was determining the triggers for compensation and whether there should be a threshold. When the committee began its deliberations, committee members representing different stakeholders were against thresholds of any kind. By the end of the two years of discussion, everybody understood why setting a threshold would be advantageous. There were also some disadvantages, but those would not outweigh its advantages.
- The committee also discussed the issue of who would pay for losses. That was a big issue, especially at a time when federal funding is so tight. Some members thought that the biotech developers should be responsible, while others thought the farmers growing the GE crops should be responsible. Others thought that taxpayers should be responsible because all Americans benefit from a greater diversity in the agricultural system.
- Another issue was how the committee should address the "co" in coexistence. Does it mean that everybody is involved or not? This is a critical issue, as can be seen

from the two quotes given earlier. The farmers, understandably, were the most vocal and felt strongly about who was responsible for preventing inadvertent presence of unwanted material and whether this was the responsibility of just one farmer or was shared between neighboring farmers.

- Finally, the committee discussed whether there should be fencing in or fencing out of any unwanted material. This issue boils down to who becomes responsible for that buffer zone. Should biotech farmers create "fences" by putting border rows on their land to prevent pollen from leaving their fields? Or, should organic or IP farmers create fences by planting border rows of corn on their land so that GE pollen doesn't get to their crops?

The AC21 completed its report in two years, and its recommendations fell under the following four themes:

1. *Compensation mechanism.* The AC21 members could not reach consensus on the need for a compensation mechanism. The committee members were equally split into those who thought there should be a mechanism and those who did not think so. Everyone did agree that it was critical to gather data on kinds of economic losses. Then, if warranted, USDA could set up a pilot compensation program based on crop insurance as a mechanism to pay for those losses. Creating incentives for joint coexistence plans was suggested, as well as possibly offering premium reductions for crop insurance if neighbors worked together to try to avoid any problems stemming from unintended presence.
2. *Stewardship and outreach.* There was consensus that USDA should conduct comprehensive education and outreach to educate farmers about how to support coexistence between diverse agricultural systems. USDA should foster good stewardship, mitigate economic losses, and promote and incentivize farmer adoption through appropriate stewardship practices, tool kits, etc. That recommendation was not controversial.
3. *Research.* The AC21 concluded that the Economic Research Service (ERS) should conduct research to quantify the actual economic losses incurred by farmers as a result of unintended presence and how those losses have changed over time. Farmers need help to develop techniques to reduce the likelihood of coexistence causing losses.
4. *Seed quality.* Finally, the AC21 decided that it is important to collect data from seed companies on unintended GE presence in the seed supply. The committee was clear in understanding that very pure seeds increase the likelihood of meeting thresholds. If seeds already have some level of unintended presence, then a multiplier effect is introduced, which makes compliance challenging. Therefore, the last recommendation focused on seed quality—to make sure seeds would be available for all the different markets so that farmers can grow what they want and what consumers want.

Twenty-two of the 23 AC21 members supported the report. Eleven wrote separate comments, and the report was completed in November 2012.

In the report comment submitted by CSPI, we suggested that USDA should propose actions to foster coexistence when a GE crop obtains nonregulated status. In other words, when USDA makes its final decision finding that a GE crop is not a "plant pest," it shall simultaneously issue recommendations about how to carry out coexistence. USDA shall provide best practices for farmers planning to use that new GE crop, as well as for farmers using the non-GE version of that particular crop. This was discussed several times with the whole committee, but there was no consensus.

A second suggestion was to require biotech seed companies to include coexistence measures as part of their seed contracts. As was stated earlier, many farmers are required to plant refuges under their seed contracts for *Bt* corn. Seed contracts routinely have IP requirements, and there is no reason they could not also include a requirement to facilitate coexistence with their neighboring farmers. That would encourage farmers to get more of that "co" into coexistence.

The final suggestion was that USDA should provide incentives for farmers to carry out coexistence measures on their farms. USDA offers farmers incentives for many things: getting crop insurance, taking certain actions to reduce premiums on crop insurance, participating in conservation programs. Incentives can work well if properly used. Farmers cannot be forced to use them, but incentivizing using coexistence measures should be a priority.

USDA Actions since the AC21 Report

Since the report's release, the USDA has taken a number of steps. First, USDA provided the public with an opportunity to comment and received about 4,000 comments, most of which were simply in opposition to the growing, production, and marketing of GE crops. Many comments did not address coexistence, focusing, instead, on banning GE crops and labeling foods and ingredients made from GE crops. Few comments addressed the AC21 report. The comments received demonstrate the pent-up frustration about issues surrounding GE crops, and any time there is a comment period, there will be comments about these issues, whether they are relevant to the specific matter at hand or not. When Secretary Vilsack summarized those comments at the meeting in March at North Carolina State, he said, "Unfortunately, in the majority of the comments and in much of the dialog the conversation about coexistence appears to be backsliding towards more inflexible and strident contrasting positions. It has devolved into bitter rhetoric about what is good or bad, right or wrong. Very rarely is the world so black and white, and agriculture is not an exception." The USDA had hoped for constructive comments on how to help with coexistence but instead found intractable positions on both sides.

There were several comments, including one from CSPI, about using the noxious weed authority. Kathleen Merrigan mentioned that it can be used to address environmental economic harms or at least help mitigate them in her opening remarks to this conference. USDA needs to look much more closely at this option. The issues biotech crops raise today are not food safety issues, but rather environmental or agricultural impacts that could be better managed. The noxious weed authority could be used to address those, so I hope USDA will consider this in the future.

The actions taken by USDA on coexistence after the report in 2012 include:

- Funding research projects related to gene flow and stewardship to reduce unintended presence
- Improving the crop insurance program
- Implementing the organic seed finder
- Looking into non-GE and organic seed varieties

In 2015 USDA announced some new activities on coexistence issues, including an ERS study on implications of coexistence, a survey of organic farmers and actual economic losses due to unintended presence of GE, and the development of coexistence education and outreach strategies. These are actions directly related to the AC21 report. USDA is also establishing best management practices for germplasm and breeding stocks; ensuring pure seed stocks; providing information to farmers to facilitate growing of IP products; and offering tool kits to reduce unintended gene flow and postharvest mixing. The agency has adopted part of the recommendation to look into how farmers can maintain coexistence when a new GE product comes on the market. USDA plans to ask companies involved in developing seed to voluntarily look at conflict analysis during deregulation processes with USDA to understand the economic conflicts. Conflict analysis is a good first step, but this process should be mandatory rather than voluntary.

USDA has also mentioned that it will explore the potential use of conservation programs to improve coexistence, wherein a farmer can both conserve land and use it as a buffer for coexistence with neighboring farms. It also mentioned the introduction of a process-verified program for non-GE crops and processes. In May 2015, USDA acknowledged its first process-based claim for non-GE corn and soybeans. However, as Kathleen Merrigan said, the problem here is that the standard is set within companies, when a federal standard is needed.

A Path Forward

So what is the path forward, and how can the agricultural community start addressing some of these issues? First, it is important to move beyond the question of whether there have been farmers who have had economic damages. USDA has proposed some narrow research in this area, but it is too little, and it is taking way too long. While USDA wants to survey organic farmers about their damages, it also needs to survey growers who produce for the non-GMO market (such as for Europe). USDA should look at data throughout the food chain to document what works and what doesn't work. Analyzing data from farmers and industry companies that have avoided economic losses can be as valuable as evidence of where a problem arose. Asking questions such as how they succeeded and what practices they used could be extremely important in understanding coexistence.

Second, there is some economic data on coexistence that can already be used by USDA and stakeholders to get an understanding of coexistence problems and what to do about them. Data is available in the Organic Trade Association's GE white paper, which reports on samples taken from members' farms. The data simply shows that it is clear that some

samples—more in the case of corn than in soybeans—don't meet the thresholds (e.g., the EU threshold of less than 1%), while the vast majority do meet thresholds. However, this shows that some loads are rejected, as is confirmed by the personal experiences of companies in the market. Since the market will pay less for GE than for certified GE-free products, this represents an economic impact on the farmer.

Nicholas Kalaitzandonakes from the University of Missouri also provided data at the North Carolina State meeting. He stated that in cases of "declared incidents of rejection (the vast majority didn't get rejected), 1 in 4 was due to GE content." While it is not easily quantified, the data clearly shows that rejections occur, and some of those rejections are because of GE. If USDA and the public want to support all different forms of agriculture, they need to figure out a way to address that and make it right.

Third, a voluntary conflict analysis and a proposed coexistence plan are not sufficient; those actions need to be required. At the least, USDA should offer incentives to applicants to do these voluntarily when they submit their petitions for nonregulated status. If the analysis is not voluntarily submitted, USDA should conduct it before ruling on the nonregulated status petition. It does not need to be part of the decision regarding nonregulated status, but it should be part of being a steward of agriculture. As a matter of policy, best management practices and coexistence requirements should be included with every release of a new crop variety—GE or non-GE.

Fourth, the "co" in coexistence involves everybody acting responsibly to foster coexistence. It should be made a requirement in all seed contracts. Farmers are used to signing contracts for seed already, so adding a new provision is not burdensome. This coexistence facilitation should not be exclusively for GE farmers, but I think they have a particular responsibility to work with their neighbors. The seed industry has stated that 90% of farmers already work with their neighbors to facilitate coexistence anyway, so such a provision should be very easy to comply with.

Incentives—such as coupons—could easily be given for coexistence plans between neighbors, just as incentives are given for other practices. Monsanto sells famers Roundup-resistant GE seeds to use in combination with Roundup, and they offer farmers coupons for the three other herbicides needed for plants that have become Roundup-resistant.

Finally, the whole agriculture community in the US needs to be creative, even if that means using existing programs such as crop insurance, conservation programs, or pinning maps for an additional purpose. Agriculture is strongest when it can use all the forms of production to meet different consumer demands. In the end, everyone benefits when consumers have confidence in US agriculture's products. Agriculture should strive to give consumers the food they want. Farmers want to be able to meet all their different customers' needs, and US agriculture should be able to meet both domestic and international market demands. The more stakeholders argue over coexistence, the less all of those happen.

Conclusion

Coexistence may not be a big issue yet, primarily because so far there are only eight, or maybe by now nine, genetically engineered crops. As other crops start having engineered

varieties, coexistence could become a bigger issue, depending on the biology of those crops. Most farmers get along, and they use multiple production methods now, but everyone needs to be involved in the "co" in coexistence.

USDA needs be the country's leader on this issue by showing farmers involved in all parts of the food chain that this is a priority. The Vilsack administration has been a leader at times and very quiet at other times. The messages surrounding coexistence must be stressed every time the agency goes out and meets with farmers; it must be an integral part of agency policies and must be repeated by all USDA spokespersons so that it reaches everybody involved with agriculture. As Secretary Vilsack recently stated, "Coexistence has to be more than a buzzword. It is our only viable option. That is why it is time to move beyond this idea of one side winning and one side losing. There is a better way. A solution that acknowledges agriculture's complexity while celebrating and promoting its diversity."

Speaker Profile: http://www.cspinet.org/about/cspi_staff.html

Q&A

T. Reddick, Global Environmental Ethics Counsel, LLC: There is actually a lot going on regarding coexistence of unapproved crops in, e.g., China, versus other crops, and my question for you is this: Don't we have a role for common law here? Because there is a court in Kansas City that will decide whether Syngenta had a duty to get China's approval before marketing as well as a duty to maintain IP production throughout the chain of commerce. That is actually mentioned in its regulatory application and it is being now held to a common law duty for talking about coexistence, but not maintaining coexistence. I wonder if you have thoughts on whether there is a role for the states in setting up IP common law obligations that then dictate what we should do in agriculture throughout different sectors.

Jaffe: I think there is always a role for the state, whether that is impending maps or setting grower districts, etc. There are many ways the states can get involved and work with their farmers to have good coexistence. I'm a lawyer and for me it is fun to go to court and it is fun to have cases, but I think in the end we don't make the best policy by having courts make policies and decisions. I want to think of courts as the spot of last resort, not the place to establish law, and I think others would agree. It would be better if Syngenta had put together policies beforehand that didn't in fact lead someone to having to bring them to court to address that issue. The industry has used the word "stewardship," a lot, and in some cases they do better on stewardship, in others they don't do so well. If stewardship is not working you need to have some government oversight or some other regulation because the marketplace isn't working. Stewardship being part of that marketplace, or self-regulation as you might call it. I guess I don't want to jump right from stewardship to court. I would rather have an intermediary, whether that is soft regulation, as Rick Roush said, or a little harder regulation, as I propose. The alternative of going to court is always rolling the dice.

The court might say something. It might not say something. It might say something that might backfire even on the person who wins and cause more heartache and problems in the future. So my suggestion would be, let's avoid courts first and foremost.

S. Shantaram, University of Maryland of the Eastern Shore: This question has been around for almost 15 years: before GM crops came along—this is the pre-biotech era—there was organic agriculture and there was nonorganic agriculture. They coexisted on their own terms. Now GM crops are joining the nonorganic group. So why don't the same principles of coexistence that existed then apply here? Why is there is so much of this discussion of banning and debating?

Jaffe: I agree that coexistence existed before biotech and will exist after biotech. Many say that organic is rule based so you don't have to actually test. You can have pollen from GE corn get into your organic field and it can still be certified as organic because you didn't plant the GE seeds and you had a decent organic farm plan to prevent that event from happening. You can actually sell that. That is the regulatory side, but there is the marketplace, and the marketplace is different from the regulatory world. Maybe there are thresholds in the marketplace, but there are customers/consumers who want something different. Unfortunately, this is not unique to biotech. But since biotech traits are invisible to the normal eye, the consumer can't tell the difference: It is easier to tell the difference between blue and white corn and you can see that unintended presence. In the case of biotech crops, you can't see the unintended presence and yet it can have all these economic impacts. So the issue isn't that this hasn't happened before, but it didn't have the same economic impact. You might have an organic farmer who followed the rules, but if there was an unintended presence, nobody tested for it. They didn't look for the number of conventional kernels. They couldn't even tell what a conventional kernel was. It is biologically different for some today than it was before biotech. There are members of AC21, farmers who grow GE crops, who feel that the responsibility is different. Beforehand those responsibilities lay solely with the person doing the identity preservation to meet their market expectations. And there clearly are a number of people on the AC21 who feel very strongly that that is still the case. But I would argue that those biotech farmers can benefit from growing biotech crops and have some role and responsibility. I think that US agriculture as a whole benefits from having all of them—GE, non-GE, and organic—and being able to service all of them. It helps all farmers and I think therefore there should be some "co" or shared responsibility in it for all. I think that broadens the pot for everybody as opposed to saying it is one person's responsibility alone.

S. Pueppke, Michigan State University: I want to follow up on what S. Shantaram said. There is a pretty long experience with different colors of corn varieties, and my recollection is that the stringency of IP is strong there. You can't have very many kernels of the wrong color. Is there anything that you can learn from those processes about coexistence?

Jaffe: Many of us on the AC21 felt there was something to learn from this, and I think USDA was surprised that in the comments on coexistence and how it has worked in the past they didn't get any on this particular issue. Now USDA has to go out and investigate

this much more specifically for themselves when they had expected that data would come to them. There are lots of other examples, and we can learn how to apply them here. They expected that those examples would come to them via the public comments. That was not the case, so they have to go out and find them, investigate them, and figure out for themselves what best management practices work and how we can learn from them. I agree with you that good examples are out there and that for some reason, possibly because of the polarization of this debate, people were not interested in working with USDA by providing examples.

R. Giroux, Cargill: Steve, you talked about yellow corn or waxy corn or blue corn or other systems, all of which involved conversation and discussion with food supplier and producer. Now we have reasonable thresholds, I think it's 5% in waxy corn. That threshold was never really challenged, so if I was a corn grower and grew waxy corn, I would know that I had to have less than 5% non-waxy kernels present. If didn't meet that performance goal I would get turned away. So I would work really hard on improving my methods to meet that goal. As I see the challenge as discussed at the AC21, the basic tenet of the agricultural commodity system is that farmers take on responsibility for what they grow. It is the difference that exists between what happened in the past and what's happening today. Times change. Society changes. I'm not questioning that, but I am saying that is the basic change as it applies to specialty trades. Now, if one wants to argue that organics aren't specialty crops, we can have that debate, but that is what has changed. It almost feels to me like a self-inflicted wound from the organic perspective. You had a standard that allowed you to have some level of GM, but individual contracts say the crop must test completely negative. Is the issue that the contracts and the expectation of the consumers on the one hand and those of the producers on the other hand are different? Is it an unattainable standard? What is going on here? Why can they not meet the organic standard? Is it the contracts or the standard? That is what is not clear to me.

Jaffe: Other people have more expertise than I about what has happened with waxy corn and all those other examples, but my guess is that some of those farmers help each other to meet that 5%. They may talk to them about when they are going to plant. They may agree on the timing of planting. I think although the ultimate economic responsibility is on the grower planting the IP crop, but they may also bargain and work with each other. Clearly if there is a benefit for one farmer to have a buffer zone, he might pay the neighbor part of their premium. And I don't think these arrangements are happening often in the biotech arena. You may be right about "fence in" historically. But what actually happened at the farm level was that coexistence then was more of a give and take, and what I'm asking for is that we should aim for that type of cooperation, because they will all benefit from growing the specific crops they choose to grow. Biotech farmers grow the biotech crop because they expect a benefit from it. They don't want to grow a conventional crop. And the organic farmer also gets benefit from growing organically. They have a mutual interest in both being able to continue doing what they want to do and therefore work together to achieve that. I think that's part of it. The numbers driving this are the market contracts, not the organic standard or the government regulations or policies. If you are

a farmer and you contract for an unconscionable number like 0%, I think that you bear all the responsibility for that, because it's unreasonable. If you sued your neighbor in court because you didn't meet that 0%, the court would rule against you, since it was so unreasonable and biologically impossible that you bore all the burden of that. On the other hand, if you had a contract with a 10% threshold and you didn't meet it because of your neighbor's practices, maybe you could claim it was your neighbor's fault: If you did everything right, followed all standards and followed your required management plan, while they acted recklessly and 10% of their pollen drifted to your farm, then the court could decide based on a reasonable number to be expected given the biology of that crop, the marketplace etc., and where the responsibility begins to split. I think that is market driven. A farmer who does not have a viable contract pays higher premiums and has lots of responsibility, while neighboring farmers don't have to take on the responsibility for that. But in general they have some joint responsibilities. My answer to Tom before was that I would prefer courts not be the ones making that decision, but if you had enough of these economic lawsuits over time, the courts would eventually help to define what a reasonable contract was.

K. Merrigan, George Washington University: I'm here for historical fun and I just wanted to share a piece of information that may be interesting to the crowd: When we were running the final rules for the National Organic Program standards, there was tension about whether this is a process-based standard or are there certain requirements that the actual products have to meet. It did not take brilliant minds to look into the future and realize there may be those same sorts of threshold issues that consumers would demand for an organic product around GM in the same way it is for pesticides. It was a really big decision and it actually went to President Clinton. How many issues go to the president? I remember President Obama saying in a cabinet meeting that when decisions come to his desk they are the worst possible kinds of decisions, because as they go up the hierarchy they are supposed to be resolved. And every time they can't get resolved they get kicked up another layer. So by the time they get to the level of a presidential decision, you know it won't be an easy one. So there I was, as a young administrator of an agency in the White House, in the West Wing, in the Roosevelt Room, talking about whether or not there should be a threshold for organic standards. And the decision was really determined by the advocates for biotechnology in the administration who felt that this threshold decision around what constituted a GMO-free claim should not be decided within the context of the organic rule-making, that it should be a broader discussion. But this historical note that the organic industry did grapple with this and had built consensus around a way to move forward, but it was actually the biotechnology advocates who stopped them in their tracks at the White House, in the West Wing, with the president.

Agricultural Biotechnology: Facilitating Trade for Food and Feed

Sharon Bomer Lauritsen
Office of the US Trade Representative

I am delighted to speak to you about stewardship and sustainability in agriculture, especially as they relate to the element of international trade. The Office of the US Trade Representative (USTR) is a small government agency. We are responsible within the Executive Office of the President for developing the government's trade policy, negotiating trade agreements, and enforcing trade agreements.

Sustainability is like a stool with three legs, the environmental, social, and economic, and too often the economic leg gets left behind. And even when they are investigated, the economics of trade in the products of agricultural biotechnology are not always fully incorporated. A part of the job that I do every day is to help the US government, our ag stakeholders, and Congress understand the trade impacts of domestic issues and regulations such as insect resistance, herbicide resistance, because we have to take those into account for international trade. It is critical that we consider international trade impacts of new products coming to market and consider their stewardship necessary.

Opening and maintaining markets for US agricultural products, including those derived from agricultural biotechnology, is a top priority for the US government. We have a multi-agency, interagency process that works on these goals; USTR, USDA, the State Department, and all the US regulatory agencies cooperate in these efforts and coordinate to make sure that the use and trade of biotechnology products help US farmers compete in the global marketplace and help make US agriculture more sustainable.

With over $40 billion in US exports of food and agriculture products, and that is just under 25% of our total agricultural exports, derived from biotechnology, and over 90% of all US corn, cotton, soybeans, and sugar beets, not to mention large percentages of papaya and alfalfa, as well, our and other countries' regulatory approaches to biotechnol-

ogy are critical components of our trade agenda. So for today what I want to do is lay a foundation for discussions you will have for the next day and a half.

By way of background, 28 countries already are growing biotech crops—an estimated 18,000,000 farmers—and more countries are going to be added. I recently met with representatives of Vietnam, which is now conducting field trials and has new regulations in place. Adoption rates globally for the main commodities are high: 82% of soybeans are biotech, 68% of cotton, 30% of corn, 25% of canola. The growth over the last 20 years has been phenomenal, particularly for soybeans and to a lesser extent corn. And it is not just the United States. In 2012 developing countries surpassed developed countries in planted acreage. So what does that mean for trade? Some have calculated the percentage of local trade times the major biotech crops. For soybeans, nearly 100% of global trade is biotech, for corn and cotton it is about 70%, and canola is over 80%.

Keeping all that in mind, let us add in some additional complications and look at it in a slightly different way. I want to show you how trade has changed over the past 40 years. In the 1970s, regional trade agreements were originally primarily focused in South America and Europe. In 1995, which is right about when biotech was being cultivated and started to be traded, there is a substantially increased amount of regional trade agreements, but they were still within a region, within the Western Hemisphere—in Europe, Africa, and South America. By 2014, however, these regional trade agreements had crossed regions and become global.

Now let us look at the United States more specifically. We exported about $10.6 billion worth of corn to 71 different countries in 2014. That does not include any products made with corn, such as high-fructose corn syrup, just straight feed corn. And 93% of that corn is biotech. In the case of soybeans, including soybean meal and oil, we export about $30.5 billion to 110 different countries, of which 94% is biotech. In the case of cotton it is about $4.4 billion worth of exports to 68 different countries. That is 93% of our production and it is biotech.

When you add in the complications of what is coming down the road, it is no longer just herbicide tolerance and insect resistance. There is drought tolerance, higher yield, nitrogen use efficiency, insect resistance, and all the stacked combinations being developed. In the pipeline of products for soybeans there are feed efficiency, new oil profiles, disease resistance, and drought resistance.

With all those complexities, all those new products, the vast expanse of our trade obviously makes us a little concerned about what the future holds for trade issues. I will focus on some of our current issues on trade within the US government.

1. First, there is the lack of science-based regulation, particularly in developing countries. Peru, Kenya, India, Turkey are all major export markets for us. In these countries, our export markets don't have science-based regulations, and if those regulations don't function, it is obviously hard to get products authorized, which puts our exports at risk.
2. There is a second category of regulations that we call "asynchronous authorizations." By this we mean that different countries take different periods of time to

review and authorize the cultivation and import of new products or events. The poster child for asynchronous authorizations is China. China will not accept a dossier for consideration until after a product is already authorized in the country of export. We haven't quite figured out what that means for stacked products yet, since we don't always have authorizations here in the United States for stacks, depending on what the different events are. That means that China already has at least a three-year delay in their system for approving new products, products that US farmers could grow before they could be legally exported to China. The implications of this asynchrony are enormous and result in high risk, particularly as experienced last year by our corn growers and traders.

— I want to start first on the soybean side, because half of US soybean exports go to China. US soybean farmers are very careful about what biotech products they plant here and make sure that China has approved those new products before they are cultivated in the United States. But that means that our farmers are losing out on the benefit of new technology if they are having to wait four, five, seven, eight, nine years for new weed control mechanisms.

— In the case of corn, US corn exports to China, until recently, were not terribly significant. In 2008 they were under a million dollars. That is not a lot in our ag trade world. So farmers and traders took the risk of exporting corn. Then China decided they needed more corn and they bought a lot of corn from us, reaching over about $1.3 billion in 2012. China wanted the corn so much that they ignored the fact that maybe some of those new corn events weren't approved yet in China. Then in 2014, China decided they didn't want our corn anymore, that they had enough. And lo and behold, their inspection authorities found some events that were not authorized in China yet, and that resulted in a $3 billion disruption in US exports to China.

3. The third area is what we call "low-level presence." LLP can happen when an event is approved in a country of export but not yet in the country of import. This low-level presence will occur particularly in cases of asynchronous authorization. So there is a connection between the two. In 2008, the Codex Alimentarius Commission issued guidance on who would do food safety assessments for LLP situations. All three of our US regulatory agencies also already have policies in place for LLPs. But there is a lot of work going on right now, domestically as well as globally, to consider LLP, and Dr. Michael Schechtman will be discussing that in more detail tomorrow.
4. The fourth area is labeling. The US takes a science-based approach to mandatory labeling for biotech products. Here it is in simple terms: If the GE product is compositionally different from the conventional product, then the FDA requires that the difference must be on the label. However, other countries require labeling even if there is no difference in the product. And some countries, such as EU members, require labeling even if there is no novel protein left in a food product

because of the way it is processed. The prime example of trade disruptions resulting from labeling came in around 2000, when the EU imposed labeling and significantly cut off our soybean oil exports. Because European food companies were afraid of boycotts, they decided to source soybeans from non-GE countries.

5. The fifth example is a little bit more limited. In order for some countries to do the scientific reviews, they require that the technology developers do field trials in the country. China, again, is the example. If field trial permits are not granted, and currently China is not making those decisions in a timely manner, that means the technology developers can't get the science together in order to get authorizations.
6. Another issue we deal with is liability, and here the poster child is Turkey, where the liability is so severe for unapproved events or missed information from the technology developer that US technology developers aren't even submitting dossiers for approval in Turkey. Again, that disrupts our exports of corn, soybean, or cotton if we can't get these products authorized in the countries of export.
7. And then finally I must talk about the latest proposal from the European Union—what they call an opt-out provision—whereby even if the European Commission has determined that a particular event is perfectly safe, member states can decide on their own not to allow that particular event to be used in their country. This proposal undermines the common market of the European Union, and we fail to understand how a product that is determined to be safe by the European Commission cannot be allowed in individual countries. This is very important for Europe's livestock producers, who rely on biotech corn and soybeans for animal feed.

The US government focuses on opening up markets to US exports. In the case of biotechnology, we focus on promoting science-based and timely regulatory decisions. We do this in a number of different ways, what we call the sustained working level. This involves primarily the regulatory agencies and USDA's foreign agricultural service. For example, they will work to release individual shipments that have been held or work with individual countries to make sure that regulations are science based as they are being developed. In another area we work bilaterally with countries. That is often focused, as in the case of China, on starting a dialog on scientific innovation. One of our objectives is to work with China to help promote science-based regulatory decision making.

We also work with groups of countries "plural-laterally," where several organizations, including USDA, provide leadership in promoting, again, science-based regulatory approaches. We have what we call our Like-Minded Group, which we established in 2010. These are countries that also produce biotechnology, and we work together primarily in Brussels to raise concerns about European approaches and concerns, whether it is on opt-out or other issues.

A group that was initiated by Canada, Global LLP Initiative, is a slightly larger group of 15 countries that focuses on developing coordinated approaches to LLP. The USDA provides leadership in both North and South America within governments to promote

science-based decision making. Within APEC, the Asia Pacific Economic Corporation, there is a high-level policy dialog for agricultural biotechnology focused on information exchange and consensus building in the Asian Pacific region.

Multilaterally—with other World Trade Organization members—we routinely raise concerns with other countries on sanitary and phytosanitary measures: food safety, animal health, and plant health. We also have a committee on technical barriers to trade, essentially regulations, that are not related to sanitary and phytosanitary issues. And within the Codex Alimentarius the US government has dealt with various biotechnology issues over the years, including having decades-long conversations about labeling, LLP, and how to do food safety risk assessments.

We talk about biotechnology in trade agreement negotiations, most recently the Trans-Pacific Partnership negotiations with its 12 countries, under Canada's leadership. There is work to try to create a forum within TPP for information exchange and collaboration on LLP and asynchronous authorizations.

And finally, in the area of trade and technical capacity building, USDA has many projects working with third-world countries to help them develop sound regulatory systems. AID and the State Department do a lot of outreach as well.

So what is the future, and what are the key items I would like you to think about over the next day and a half? We have many current challenges associated with ag-biotech products, but they are not limited to the use of genetic engineering or recombinant DNA technology. We have new types of biotechnologies that are already here, some of which are referred to as new breeding techniques, including novel approaches such as genome editing, but there is no clear picture of how these new technologies will be regulated here in the United States or around the world. Scientific advances will continue to provide tools to improve crop varieties more precisely and more quickly, and they can help us address the suite of sustainability challenges confronting agriculture around the world. Engagements on emerging technologies will hopefully help create enabling policy environments for innovation and allow products from those innovations to be used and traded globally in a reliable manner. Farmers and businesses need predictability and certainty in the regulatory processes of other countries, and that is a need with which the US government can help. But the US and Canadian governments can't do it all, which opens the door for you to discuss later today and tomorrow the importance of stewardship on the part of technology developers to help facilitate trade for American farmers. Key to that responsible stewardship is ensuring that products are authorized in key export markets before introducing them for cultivation.

Speaker Profile: https://ustr.gov/about-us/biographies-key-officials/sharon-bomer-lauritsen-austr

Q&A

G. Thompson, Penn State: How much of the embargoes that are slowing things down by the various mechanisms you described might be due to market manipulation as well?

Lauritsen: I think that is certainly the case with China. Obviously it is a very centralized government. They very much control how much of which particular product they import. So I would say that is certainly the case with China, but less so in less centrally planned governments.

S. Pueppke, Michigan State University: You paint a complex picture of trade and I wonder if this is just the way it is in general or if there is something about food and biotechnology that is different from other items that might be traded?

Lauritsen: I wouldn't say that agricultural biotechnology is unique, but that as new technologies are introduced within agriculture, there is a shared complexity, and whether it is agricultural biotechnology or new animal drugs, there is a range of things that our farmers, ranchers, and food processors use that other countries don't or don't have processes to authorize, and that creates problems. My office, and particularly the USTR, spend a tremendous amount of resources trying to deal with trade created by a whole host of new technologies. One of the reasons our approach to China last year was focused broadly on innovation in agriculture was that, on the road to the future as we see it, this is something that is going to grow with the introduction of new technologies.

R. Hardy, NABC: About ten years ago, we were very concerned about field testing of genetically modified crops, especially in the university setting. NABC at that time published a document on best management practices. It seems to me what we are talking about here is best management practices for farming. The National Research Council periodically does studies of standards, etc. Might we not fund a National Research Council study, maybe every five years, to investigate best management practices for producing crops?

Lauritsen: I'm a big fan of best management practices and I certainly think there is a role for such a study, whether it is on coexistence or trade. How to get that out to the hundreds of thousands of farmers is a question. There is also a role for best practices within the technology developer community, particularly in regard to stewardship. All of those would be welcome.

T. Shelton, Cornell University: Right now most of the biotechnology is involved with process, with grains, etc. You also mentioned papaya and a number of other crops, and I see this opening up to tremendous complications as we look at vegetables and fruits. I recently attended a seminar where someone was talking about China and how central planning was deciding which crops to grow and which to buy on the world market. Soybeans, which originated in Asia, are a water-intensive crop, and someone in China said they are probably not going to plant much of those, because they are so water intensive, and

that water is needed for the population. They are planning to get away from producing soybeans and just buy them on the world market, in which case they probably are going to have to be much more flexible on the traits they will accept. It is market demand and survival more than rules.

Lauritsen: That is absolutely right and that is what we saw with corn last year. When they decided that they had enough corn in storage, they started inspecting and testing the corn and found a scientific reason to stop imports. And you are right, they want soybeans and they are going to buy them from us and Brazil and Argentina—all of us biotech producers. One of the conversations with the Chinese last year was that they need to get their regulatory system functioning because US farmers may decide that they will not hold back on introducing a new technology and will just send their crops someplace other than China. I don't know if that will happen, but there is a lot of grumbling among farmers who want to use new technologies, in particular crops tolerant to different herbicides. The soybean market is too important for us, and our farmers will take the risk right now, but they are certainly starting to rethink this. The other issue with China is they are developing their own biotechnology traits. I remember going to a scientific conference a few years ago, and all the Chinese in the room picked up their cameras and took pictures of all the slides and took them back. So you know they definitely want to develop their own technology—and that is one of the reasons they are slow to approve imports. They are trying to play catch-up.

S. Shantaram, University of Maryland of the Eastern Shore: What is your prediction on the opt-out in the EU?

Lauritsen: I just had a report from our office in Brussels this morning, where four major political parties in the European parliament requested that the commission take back the opt-out proposal. Those of us in government—and you will appreciate this, it tends to be a joke—know we are doing our job when nobody is happy. When you make both sides unhappy, you know you have done your job right. That's what the commission did. We never thought the NGOs and the biotech industry in Europe would both agree that this proposal was bad. The environmentalists don't like it, and the major European farm organization actually publically criticized it. A French farmer led the protest. So, nobody likes it, and maybe it was their intention to put out something so bad that it would die. We'll see.

S. Shantaram: You know I have studied this transatlantic fight over GMOs so long here in the US that it is my very informal nonscientific conclusion that this whole debate is not about safety of the technology, but totally about international money that is being paid off in different arenas. How are they going to tackle this? Most of these decisions are not being resolved. What is the solution?

Lauritsen: I will answer that in two ways. It is purely political. If you look at surveys in Europe asking, "What do you look for when you buy your food?", only 5% of the

respondents talk about GMOs. For most European consumers, GMOs are just not at the top of the list. But if you ask Europeans, "Do you care if your food is a GMO?", most will say they do, or 75% will say, "Yes we care and we don't want it." So it is how you ask the question, it is politics. They have a new commission, a new president leaning in that direction. As the US government, we will continue to focus on science-based decision making when we meet with the European food safety agency, and the working-level people there are also very much focused on trying to make science-based decisions. It is the political overlay that causes the problems. At some point in time, European agriculture is not going to be competitive. Without biotech advances, without advances in animal growth—when you travel through France and some of the other countries, you realize that the farmers there are just fine not using new technologies, and our farmers will simply go elsewhere. Europe is no longer the big market it used to be, and we spend less time on European issues—at least we did before we had to start trade negotiations with them—since it has not been as important a market as Asia in particular.

R. Giroux, Cargill: I can't possibly let the USTR leave without asking questions. But first I am going to thank Sharon for all the hard things the USTR does for us as we try to do trade. All markets are important to US agriculture. I'm sure that's what you needed to hear. Your work helps our farmers prosper here in the United States. Competition and being competitive is the number one priority and should be the number one priority for the department, as I am sure it is. I think what you have highlighted on your slides is very dramatic, it shows how we merge into a global food system. Compared to 1975, in 2015 we really have a developed global food system, and as you have noted, it is about integrating technology, not about innovation. We are innovating very well. There are lots of products. Many of them meet demands by our producers, but it is the integration step, the integration of those technologies into that global food system, that is the problem. And it is through science, it is by understanding what consumers want that we will find those solutions. I think the challenge in front of us, and one you highlighted very well, is to integrate the technology into what has become a global food system, to recognize that it is a global food system not only from a customer, but also from an origin perspective.

Lauritsen: Thanks Randy. And thank you.

PART III–PLENARY SESSIONS

SESSION I: RESISTANCE MANAGEMENT

Regulating Resistance

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When I think of resistance I always think of Palmer amaranth (I like saying Palmer amaranth rather than pigweed because it sounds like I know what I'm talking about). This plant can get ten feet tall, produces thousands of seeds, and can grow five inches in the course of three days. It is an impressive weed, and it is also glyphosate resistant.

My office is in charge of registering all pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). We also regulate under the FFDCA (Federal Food, Drug, and Cosmetic Act). FIFRA is a risk-benefit statue, and the risk of resistance is considered to be part of our regulatory decision. Obviously not when we register a new A1, because there is no resistance yet, but as we go through a re-evaluation process we will look at resistance, which we consider to be an adverse effect. So we license all pesticides used on crops, on conventionally bred crops as well as on genetically modified crops. USDA deregulates GE crops, but we also license the plant-incorporated protectants (PIPs), e.g., *Bt* crops.

Our goal is to extend the useful life of pesticides for as long as possible, to delay resistance to insecticides, fungicides, and herbicides for as long as we can without putting undue burden on the growers. We have a couple of mechanisms to do this. Anything from requiring a code of action on pesticide labels to informing growers wanting to rotate chemicals as to which chemical they are using and what alternate chemical they can use in the rotation to prevent resistance. There is also generic labeling that we promote for registrants to put on the labels. Most of the major registrants have incorporated this into their labeling, but many of the generics are lagging behind in doing so. We have recently registered an herbicide-resistant crop that is resistant to 2,4-D, so we are requiring resistance management plans for this crop as well, given what has happened over the years with glyphosate. For the PIPs we have been requiring resistance management plans for some time, although we are now starting to see some resistance there anyway.

Enlist Duo is a new pesticide that is applied to cotton, corn, and soybeans. It is a combination product of 2,4-D and glyphosate. This is the first time we have required more extensive resistance management plans for an herbicide-tolerant crop, but we are starting to see more and more herbicide-tolerant crops, and we will have similar plans to what we have imposed here for those. You can see that we are making labeling, training, and education, early identification of resistant weeds, and reporting of resistant weeds to stakeholders a requirement.

These are some of the label elements that I am going to be talking about:

- Mode of action
- BMPs (best management practices)
- Scouting
- Reporting

2,4-D and glyphosate are in groups 4 to 9, and those numbers appear on the label and indicate mode of action.

The BMPs we are requiring were developed by the Herbicide Resistance Action Committee, Weed Science Society of America, as well as Crop Life America. And most of the elements of BMPs describe cultural and mechanical practices to combat the resistant weeds. Some of the examples of BMPs are use of a broad, soil-applied herbicide such as Atrazine before planting; use of different modes of action, such as nonchemical weed controls including cultivation, cover crops, crop rotation, and weed-free crop seeds; and managing the weeds in and around the fields both during and after harvest.

One of the requirements is scouting before and after application to identify what weeds need to be controlled—their size and species. After application, scouting is done to determine the impacts, to determine whether something escaped control and what may be the likely cause.

Finally, reporting all incidents of nonperformance to Dow is required. While we were negotiating for this, we determined that the agreement should be written so that the grower will take care of the performance issue but can also call Dow for help through whatever possible means. The point here is to control the weed that escapes control by the initially applied herbicide.

As part of the terms and conditions that we imposed on Dow, we have them

- Develop a stewardship program for resistance management.
- Provide training and education materials, again so we don't run into resistance with 2,4-D as we did with glyphosate.
- Investigate nonperformance to determine if it is because the spray didn't contact the weed or if it is likely to be resistance.
- Develop a remediation plan if resistance is suspected. It takes some time to actually confirm resistance, so we want to make sure the weeds get controlled even if it is just likely or suspected.
- Annually report to us with enough information so we can hopefully figure out what is going on.

- Provide early notification so we have an early read on whether resistance is happening or not.
- Work to develop a rapid diagnostic system for resistance.

At the end of six years we pause to see whether or not we think resistance is happening despite what we are putting on the labels, despite all the efforts by everybody, and if it is, then we are likely to add additional labeling or restrictions to the product.

Registration review is a way to evaluate older chemistries. We do it every 15 years. We finished reregistration in 1997, so we will finish registration review again, in 2022. Resistance management is one of the things that we are going to be considering during registration review. Glyphosate is high on our list. Glufosinate will probably come out this summer, and you are likely to see similar resistance management plans for those two chemicals.

In the case of PIPs of *Bt* crops, we have had some general success in preventing resistance, and if you look at the requirements back in '96 and going forward, it looks very similar to what we are requiring for 2,4-D: stewardship programs, compliance, resistance monitoring, legal action, and refuge areas. Resistance would have evolved much faster without these requirements. I think for *Bt* cotton it was immediately put into place. For corn it took three years to get into place. Refuge requirements used to be structured, now they are a seed blend where the refuge is in the seed bag itself.

There is an expectation that given how *Bt* acts, resistance will build up. It is a season-long expression, so corn rootworm is exposed to *Bt* toxin throughout the growing season, for multiple pest generations of three or even up to six, and they feed exclusively on *Bt* corn or *Bt* cotton. I know there is a debate if this provides benefits for the environment. We think it does and we want to prolong its life as long as possible. There have been some areas in the country where corn rootworm has become resistant. In Iowa, Illinois, and I guess it is spreading east as well. We went to the scientific advisory panel to get advice back in 2013. They gave us a lot of advice we then turned into a framework proposal in January of 2014, requesting public comment in 2015. That comment period closed in April 2015; you can see some of the areas we are trying to improve upon, and you can go to Docket# EPA-HQ-OPP-2014-0805 (at www.regulations.gov) to look at the actual framework. The comment period is closed. We received 87 comments and we will be taking those comments into consideration as we develop our final framework for managing resistant corn rootworm.

Speaker Profile: Jack Housenger is the director of the Office of Pesticide Programs (OPP) at EPA. Before that, he was with OPP, and from 2011 to 2014, he was director of the Health Effects Division, which is responsible for managing the review of health effects and exposure data for pesticides as well as the development of human-health risk assessments. He was director of the Biological and Economic Analysis Division.

Insect Resistance Management for GE Crops: Industry Principles, Policies, and Programs

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Introduction

Resistance is a natural phenomenon, a result of evolution and adaptation to environment. When a pest population is exposed to a pest management tool, whether chemical, biological, or cultural, the individuals in that population that are genetically predisposed to overcome the management tool are more likely to survive and pass their genes on to the next generation. Over multiple generations, the genotypic make-up of the targeted pest population shifts from susceptibility to resistance. Insect resistance management (IRM) is the set of practices that are intended to slow this evolutionary process, delay the onset of resistance, and reduce its economic and environmental impact.

In the context of agricultural biotechnology, the rate at which resistance develops in target pest populations is influenced by genetic, biological, and operational processes (Bates et al., 2005; Gould, 1998). For genetically engineered (GE) insect protection traits, operational factors include the level of mortality the GE crops cause to the pest populations, the extent to which the GE traits are adopted across the agricultural landscapes and over time, and the diversity of other crop and non-crop hosts of the target pests in the landscapes (Gustafson et al., 2006). Biological factors include the intensity of selection pressure for resistance imposed by a crop as a result of the expression of an insecticidal trait; the extent to which the insect pests use alternative host plants; the dispersal, mating, and oviposition behavior of the insects; and fitness costs associated with resistance mechanisms (Caprio, 2001). Population genetics are driven by the genetic diversity of a pest population, including the number of genes involved in resistance to an insect protection trait; the frequency of alleles that confer resistance; the level of the resistance that is achieved; and the level of resistance conferred on heterozygous insects that carry one copy of a resistance allele and one of the wild-type susceptible allele. The most widely

advocated IRM techniques involve the use of refuges, or areas of a focal crop without insect protection traits, where susceptible insects can survive; the use of "high-dose" traits that cause high levels of mortality of both susceptible insects and heterozygous insects; and combining multiple modes of action in single plants (known as "pyramiding" toxins) so that insects that are resistant (or heterozygous for resistance) to one mode of action are killed at a high rate by one or more additional modes of action (Caprio, 1998; Roush, 1998; Tang et al., 2001; Zhao et al., 2003).

Developers of GE traits are able to influence certain elements of the evolutionary process of adaptation that leads to resistance. On the biological side, developers can select insecticidal traits to which target pests are highly sensitive and target expression levels and patterns (across tissues and across crop phenology) to achieve the desired "high dose" (Bernardi et al., 2012). Developers can also combine multiple modes of action in individual plants to create pyramids that are very effective at delaying resistance (Storer et al., 2012). On the operations side, developers can provide growers with information and education on the appropriate use of traits within their farming operations and on best management practices for reducing pest populations (MacIntosh, 2010). Where refuges are important, developers can instruct growers on their necessary size and placement, ensure growers are able to buy refuge seed, and even incentivize the purchase, planting, and management of refuges so that they produce both yield and susceptible target insects (MacIntosh, 2010).

However, there are limits to the extent to which technology developers can control the evolutionary process of resistance. The range of known different insecticidal proteins that are suitable for expression in plants is currently rather narrow, with a strong reliance on Cry and Vip proteins from *Bacillus thuringiensis* (*Bt*) (Bates et al., 2005). Different target pest species have different levels of sensitivity to the available insect protection traits, and thus expression levels that meet the high-dose criterion for one pest may not meet that criterion for other pests (Buntin, 2008; Crespo et al., 2009; O'Rourke et al., 2010; Wu et al., 2007). Some important target pests, such as *Helicoverpa* spp. (corn earworms, bollworms) and *Diabrotica* spp (corn rootworms), appear to not be highly sensitive to any of the characterized proteins, being able to some extent to overcome environmental stressors that include pesticidal traits (Burkness et al., 2010; Hibbard et al., 2010, 2011; Huang et al., 2011; Storer et al., 2006). Furthermore, genetic diversity within insect species and background natural mutations mean that alleles conferring resistance or reduced tolerance are expected to be present in a target pest population even before exposure to a given plant-produced insect protection trait (Burd et al., 2003; Downes et al., 2009; Gould et al., 1997; Siegfried et al., 2014). There are also limitations on a technology provider's ability to enforce IRM practices on the part of farmers, who can choose among different seed suppliers and technology developers.

From a farmer's perspective, resistance management must compete for time and attention with other priorities, particularly the need to deliver high-yielding crops, making efficient use of land, fertilizers, water, pesticides, and other agricultural inputs. Refuges are by definition lower yielding than fields containing GE insect protection traits, because to

be functional they must be fed on by susceptible insects. Refuges and best management practices also add to the complexity of raising crops and managing farms, requiring growers to handle different fields or different parts of fields in different ways.

Industry Commitment to Durable GE Crop Technology Deployment

The developers of insect-protected GE crops recognize that the development of resistance to their products can threaten their business success as well as that of their customers. They also recognize that, in the face of these challenges around implementation of refuge-based IRM, durable deployment of these crops requires cooperation among developers. Cross-licensing arrangements and similarities among the products available to growers means that resistance to one product can cause resistance to others, while resistance reduces the diversity of effective modes of action and increases the selection pressure for resistance to the others. Accordingly, in 2014, the member companies of CropLife International, the global federation representing the plant science industry that includes BASF, Bayer CropScience, Dow AgroSciences, DuPont Pioneer, Monsanto, and Syngenta, agreed together to a foundational set of durability commitments. These commitments recognize that (1) resistance management is fundamental to stewardship of the technology; (2) practices that promote resistance management should be embedded throughout organizations, including in R&D, regulatory, and commercial operations; and (3) the marketplace should not undermine technology sustainability.

To ensure that these commitments are carried out into practice, the industry further developed a new resistance management program through Excellence through Stewardship (ETS; see www.excellencethroughstewardship.com). ETS promotes the universal adoption of stewardship programs and quality management systems for the full life cycles of plant products. Adding IRM programs to the existing scope of ETS ensures transparency and collaboration in efforts to meet the industry commitments to technology durability. The ETS program requires that science-based, practical, IRM plans be in place for all insect protection traits, that there be industry-wide alignment on local IRM strategies, that appropriate refuge seed be available and distributed to growers, that grower IRM adoption programs be in place, and that monitoring be in place for the effectiveness of these programs, with mitigation measures should resistance develop. ETS achieves adherence to these programs through regular audits of member companies' programs and processes. The IRM component was added to ETS at the start of 2015, and the multinational companies that commercialize insect protection traits are committed to successfully completing audits by the end of 2016.

The ETS audits will cover a member company's management accountability for IRM, and strategies, processes, and programs that address regulatory requirements, market deployment, sales and customer IRM awareness, grower implementation of IRM requirements, resistance monitoring, and responses to reports of potential or actual resistance. ETS auditors will examine company records and documentation of these processes, ensuring improved transparency and accountability across the technology developers.

Non-Industry Stakeholder Engagement

It is clear that the challenges around implementing IRM at the grower level require not only dedication by the technology developers but also the direct involvement of other stakeholders that have an interest in sustainability of biotechnology in agriculture (Frisvold & Reeves, 2010). Regulatory authorities and other government agencies can promote IRM for beneficial products that increase farmer productivity and reduce the environmental footprint of agriculture. Regulatory agencies, such as the US Environmental Protection Agency and the Canadian Food Inspection Agency, that require developers to implement refuge compliance programs have proven to be effective in raising IRM implementation by growers to high levels (Carriere et al., 2005, 2012; US Environmental Protection Agency, 2014; Tabashnik et al., 2013). Regulatory and government policies can also be adopted that encourage the development of insect protection products with favorable resistance risk profiles, such as those that have multiple modes of action and that incorporate refuge seed blended with GE insect-protected seed (Carroll et al., 2012; Head et al., 2014).

For regulatory and technology provider IRM programs to be fully effective, they must be embraced and promoted by all stakeholders that influence agricultural practices and growers' use of GE crops. Seed companies, retailers, and licensees are often the first source of information for growers on selection and management of their crop seeds, at both ordering time and delivery time. Public extension services and private crop consultants play an important advisory and management role for many growers and so need to promote consistent information for their clients. Grower groups and associations also play an important role in providing information and advice to their members. This is exemplified in the US by the National Corn Growers Association, which provides advice and educational tools for farmers growing GE corn (see http://www.ncga.com/for-farmers/best-practices/integrated-pest-management-practices). University and other public sector researchers have played, and continue to play, a pivotal role in developing data and other information that are the cornerstones of effective resistance management, and in promoting science-based resistance management programs with regulators, technology developers, and growers.

It is the mission of federal and state departments of agriculture to promote sustainable and efficient crop production; they play a key role in researching and advocating IRM for GE crops. For example, within the US Department of Agriculture (USDA), the Agricultural Research Service (ARS) conducts research into *Bt* resistance evolution; genetics and ecology of lepidopteran pests (at the Corn Insects and Crop Genetics Research Unit, Ames, IA); resistance evolution and characterization for corn rootworms (Plant Genetics Research Unit, Colombia, MO); and impacts of *Bt* resistance on cotton pest management (Southern Insect Management Research Unit, Stoneville, MS). USDA's National Institute for Food and Agriculture has supported research on resistance management for GM crops and works with ARS to fund biotechnology risk assessment grants. USDA's Economic Research Service studies adoption of GE crops and the economic impacts of resistant pests and resistance management programs. Such research programs provide valuable information that helps the design and implementation of effective, practical resistance management and mitigation programs for GE crops.

Conclusions: Resistance Management Supports the Sustainability of GE Crops

Genetically engineered crops have become important components of sustainable crop production systems. By reducing the need for soil tillage and insecticide applications while supporting high yields, they have boosted agricultural productivity and farm incomes while preserving ecosystem services and reducing the environmental footprint of agriculture (Brookes & Barfoot, 2012; Carpenter, 2011; Klumper & Qaim, 2014). These benefits have accrued in both developed and developing countries (James, 2010). Insect resistance management programs that are flexible, practical, and effective contribute to the ability of GE crops to help meet broader sustainability goals (National Research Council, 2010).

IRM programs for GE crops have been widely implemented for 20 years with a strong record of success (Tabashnik et al., 2014). The vast majority of insect pest populations remain susceptible to the insecticidal proteins that target them, and there is no documented field resistance in such economically impactful species as *Heliothis virescens, Ostrinia nubilalis*, and *Helicoverpa armigera* (Tabashnik et al., 2014). Resistance development tends to be associated with insufficient implementation of IRM programs, such as use of single-mode-of-action products without refuges. However, even where resistance has developed to one *Bt* protein, the resistant populations remain susceptible to one or more other *Bt* proteins. For example, *Spodoptera frugiperda* populations that are resistant to Cry1F are susceptible to Cry2Ab2 (Huang et al., 2014), and *Diabrotica virgifera virgifera* populations that are resistant to Cry3Bb1 remain susceptible to Cry34Ab1/Cry35Ab1 (Gassmann et al., 2014).

Continued innovation, enabled by past success and encouraged through appropriate regulations, will be needed to expand the benefits that have already been experienced. The first-generation single-mode-of-action insecticidal traits have now been largely replaced by crops with multiple proteins with differences in their modes of action. Along with technological innovations, the development and launch of new stewardship initiatives, such as the ETS IRM module, will continue to advance the role of GE crops in a sustainable agriculture that can provide food, fiber, and fuel for a growing global population.

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Herbicide-Resistant Crop Management: A Canadian Perspective

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Introduction

In 2014, the top five genetically modified (GM) or transgenic crop producers were the United States, Brazil, Argentina, India, and Canada, together accounting for 90% of the global area of these crops (James, 2015). The United States has 40% of the area; Brazil, 23%; Argentina, 13%; India, 6%; and Canada, 6%. Although GM cultivars of 11 crops have been released, 4 crops cover 99% of the GM crop area. Soybean (*Glycine max* L. Merr.), corn (*Zea mays* L.), and cotton (*Gossypium hirsutum* L.) are the main GM field crops grown in the US, whereas soybean dominates the cultivated area in Brazil and Argentina. In Canada, canola (*Brassica napus* L.), soybean, and corn are the main GM crops, while cotton is the only GM crop grown in India.

Herbicide resistance (HR) is still the dominant trait in GM crops (86% of total), 20 years after their introduction. Single-trait HR cultivars account for 58% of GM crop area, single-trait *Bacillus thuringiensis* (*Bt*), for 14%, and stacked traits (HR+*Bt*), for 28%. In Canada, the adoption rates of GMHR canola, corn (grain), and soybean in 2014 were 98, 91, and 80%, for total cultivated areas of 8.08, 1.23, and 2.24 million ha, respectively. Canola is mainly grown in western Canada, in contrast to corn and soybean, which are mainly grown in eastern Canada.

HR Crop Deregulation: Herbicide Resistance Stewardship/ Management Plan Requirements

Since 2004, the Plant Biosafety Office, Canadian Food Inspection Agency, has required applicants for the deregulation of an HR crop to submit an herbicide resistance stewardship or management plan (CFIA, 1994, 2014). Specifically, the applicant needs to address the following: (1) control of volunteers, as well as identification of any potential changes

in agronomic practices related to the HR trait that could impact sustainability, e.g., soil conservation; (2) selection of herbicide resistance in weeds resulting from the potential continued application of the same herbicide in subsequent rotations, i.e., guidelines for rotation of crops and herbicides; (3) introgression of the HR trait into related species; (4) management of the HR crop during the growing season, especially where multiple resistance due to cross-pollination could arise in subsequent growing seasons; (5) communication to growers and an efficient mechanism for them for reporting problems; and (6) monitoring the effectiveness of the stewardship plan.

Herbicide Registration: Mitigation via Resistance Management Labeling

Resistance management symbols and statements on product labels have been required since 1999 by the Pest Management Regulatory Agency (PMRA) (Beckie et al., 1999). That directive (PRO99-06) was updated in 2013 (DIR2013-04; PMRA, 2013). The site of action (group) number(s) is located on the front panel of product packaging, with resistance best management practices (BMPs) in the use directions. These BMPs, which are the same for all herbicide products, ask the user to do the following: (1) Where possible, rotate use of the product and other herbicides in its group (as defined by site of action) within a growing season (sequence) or among growing seasons with herbicides from different groups that control the same weeds in a field. (2) Use tank mixtures with herbicides from a different group when such use is permitted; to delay resistance, the less resistance-prone partner should control the target weed(s) as effectively as the more resistance-prone partner. (3) Apply an integrated weed management program that includes scouting and historical information on herbicide use and crop rotation and also considers several other practices. These are tillage (or other mechanical control methods); cultural (for example, higher crop seeding rates, and precision fertilizer application method and timing to favor crop over weeds); biological controls (weed-competitive crops or varieties); and other management practices. (4) Monitor weed populations after herbicide application for signs of resistance development (e.g., a weed species on the herbicide label is not controlled). If resistance is suspected, prevent weed seed production in the affected area, if possible with an alternative herbicide from a different group. Prevent movement of resistant weed seeds to other fields by cleaning harvesting and tillage equipment when moving between fields, and planting clean seed. (5) Have suspected resistant weed seeds tested by a qualified laboratory to confirm resistance and identify alternative herbicide options. (6) Contact a local extension specialist or certified crop advisor for any additional pesticide resistance management and/or integrated weed management recommendations for specific crops and weed biotypes. (7) Contact the producing company for further information or to report suspected resistance. The above points constitute a standard statement for products containing one or more active ingredients from the same group. For products containing two or more active ingredients from different groups, the statement would be modified to reflect the situation.

Monitoring/Surveillance of HR Weeds

A framework for postrelease environmental monitoring of GM crops facilitates this process, and weed surveys are an important element of such a framework (Beckie et al., 2010). My first HR weed survey was conducted 20 years ago! Periodic random field surveys of HR weeds should be led by a public institution, usually within its provincial or state boundary. Grower management questionnaires may accompany field survey data collection; correlation analysis can identify reduced-risk practices (e.g., Beckie et al., 2008). Surveys are supplemented by testing samples of suspected HR weeds submitted by growers to a qualified laboratory and publicizing occurrence via HR weed maps (e.g., Beckie et al., 2013). These combined activities allow close tracking of HR weed occurrence in time and space and facilitate early grower awareness and timely management.

Stacked-HR Trait Soybean and Canola

The seed industry's response to the perfect storm comprising rising incidence of glyphosate-resistant (GR) weed populations and concomitant lack of introduction of new herbicide sites of action (the last introduction occurred in 1982) is commercialization of stacked-HR trait cultivars in our major crops. Currently, there are four GR weed species in Canada—Canada fleabane or horse weed (*Conzya canadensis* L. Cronq.), giant ragweed (*Ambrosia trifida* L.), common ragweed (*Ambrosia artemisiifolia* L.), and waterhemp (*Amaranthus tuberculatus* (=*A. rudis*) L.—all in southwestern Ontario in the GR corn/soybean belt, and GR kochia (*Kochia scoparia* L. Schrad.) in western Canada. GR kochia has been selected primarily in chem-fallow areas, but is also found in cereal, oilseed (e.g., GR canola), and pulse crops (e.g., Beckie et al., 2015). Currently, between 50 and 100 sites with confirmed GR kochia exist in the three prairie provinces. The most recent surveys in Ontario indicate that GR horseweed is most prevalent (155 sites in eight counties), followed by giant ragweed (71 sites in five counties), common ragweed (5 sites in one county), and waterhemp (<5 sites in one county) (Byker et al., 2013; Van Wely et al., 2015).

Therefore, stacked-HR trait crops such as soybean are widely viewed as a necessary, albeit interim, tool for managing GR weeds. Roundup Ready 2 Xtend (glyphosate + dicamba) was approved in 2012 in Canada; it will be available in 2016. Dicamba is applied at 600 g ai/ha (or 300 *fb* 300). The environmental impact (EI) per hectare is 15.8, a moderate rating (Beckie et al., 2014). Adoption will probably be very rapid, as RR2 Extend will be the Monsanto platform for all future soybean cultivars; in addition, Pioneer announced it will be going with RR2 Extend and dropping the development of Enlist (glyphosate + 2,4-D) soybean (P. Sikkema, pers. comm.). Therefore, the adoption of the latter HR system will likely be slow, simply because the two largest soybean seed companies—Pioneer and DeKalb—will not be carrying this trait (P. Sikkema, pers. comm.). Enlist soybean was approved in 2013 in Canada (available in 2016). 2,4-D is applied at 834 g ai/ha, with two sequential applications the maximum. The resultant EI from the two applications would be 25.6 (high) (Beckie et al., 2014).

Stacked-HR trait canola (Roundup Ready 2 Xtend) is expected to be approved and released in the next decade (after corn). Cultivars will likely have a three-way stack, with glufosinate added. Dicamba-HR canola would be susceptible to another auxinic herbicide,

2,4-D, commonly used to control volunteers. What are the management implications? Dicamba is currently applied at 140 g ai/ha to 10–15% of wheat and barley fields (two crops covering 50% of the annually cropped area) in western Canada. Increasing the areas of soybean and corn (including cultivars with this stacked trait) across the Canadian prairies will increase the dicamba selection pressure for HR weeds (300–600 g ai/ha rate structure). Growers will need to tank-mix another herbicide with dicamba or use an alternative to dicamba to control canola volunteers in cereal crops grown the following year.

Auxinic Herbicide Resistance Risk

Currently, there are 31 group 4 or synthetic auxin-HR weed species (Heap, 2015). However, 5 of these are grasses or monocots, resistant only to quinclorac (a quinoline carboxylic acid). The aster (Asteraceae) and mustard (Brassicaceae) families disproportionally account for 40% of remaining HR species. The inheritance of resistance is often attributed to a single, dominant to semidominant gene. The cross-resistance pattern among classes (phenoxy, benzoic acid, carboxylic acid) is generally unpredictable (Beckie & Tardif, 2012). Therefore, given the above characteristics, a significant increase in the intensive (herbicide load) and extensive (regional area) in-crop use of synthetic auxins will undoubtedly parallel or duplicate the scenario of the rise of GR weeds observed from 2000 to the present day. Both site-of-action herbicides are considered inherently low risk relative to other groups, but risk dramatically rises when the application threshold is exceeded.

Technology Stewardship Agreement and Use Guide: Improving Stewardship

Growers do not usually read the technology-use guide after they purchase GM crop seed. Mandatory training sessions for growers would enhance adoption of BMPs. The seed industry's main objective is to regulate planted seed. Contrary to the stipulation in the HR stewardship/management plan, it does not really monitor the effectiveness of these plans. Feedback that growers may volunteer is not publicized. Recommendations are needed on herbicide-use intensity (e.g., multiple applications of glyphosate, dicamba, etc., in a field every year) and HR crop rotation frequency thresholds (e.g., back-to-back canola cultivation). Enhanced industry and federal and provincial/state government incentives (e.g., crop insurance) are needed to increase adoption of BMPs. Perhaps a useful model to emulate is GMHR canola and cotton cultivation in Australia (Werth et al., 2008). For example, glyphosate is not recommended the year following GR canola, and two post-herbicide surveys are stipulated in any season that GR cotton is grown.

Summary and Conclusions

The reality is that proactive HR weed management is rare. Growers, especially when they are renters rather than owners, greatly discount potential future rewards relative to present ones. In Canada, renters farm nearly half of all cultivated land. In a nutshell, that socio-economic factor is the basic reason for the lack of proactive grower attitudes and actions.

Which direction are we going? Likely not "the road less traveled." Cultivars with stacked HR traits (e.g., glyphosate + glufosinate + dicamba) will provide a short-term respite

from HR (including GR) weeds, but they will perpetuate the herbicide treadmill and accelerate the selection of multiple-HR weed populations in the longer term. Industry stewardship plans need teeth. To avoid a "tragedy of the commons," recommendations for maximum herbicide-use intensity (within and across growing seasons) and HR crop rotation frequency are needed. Concomitantly, industry and government incentives must expand to improve grower adoption of BMPs for HR crops and HR weeds. The only long-term solution is for government or end users of commodities to set herbicide-use reduction targets in our major field crops similar to those set by European Union states. Government agricultural policy should include financial incentives and/or penalties in agricultural programs to support these targets. The only sustainable solution is herbicide-use reduction, incentivized by government programs.

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Resistance Management

Q&A

MODERATOR: DAVE MORTENSON

J. Newsome, University of Arkansas: In this module we have talked a lot about implementing best management practices and getting that information to growers. Obviously, that is not unique to biotech. My question is if you expect that precision agricultural technologies such as variable rate planners and things like that will play a role in the operational aspect of resistance management?

Beckie: Very good question. I wrote a paper on the future of weed control, from a weed control aspect. Today, we have drones. In my opinion, drones are very useful for monitoring and surveillance and the technology is rapidly advancing. We will have to work with FAA stipulations about how far they can go without sightline, etc., but drones are certainly one aspect of precision weed control. We have done a lot of research on weed patch management using GPS, whether in combines or in tractors, mapping weed patches and monitoring them to make sure they don't spread. I see a big role for precision agriculture in terms of mitigating weed resistance.

B. Gwin, Ohio State University: If we want to plan ahead we should use previous records, online tools, things along that line to preempt rather than remediate. Any comments on that?

Storer: I'll tackle that from an insect standpoint. Last I recall, rootworm is very localized in a field, and if we get to the point where that can be recognized early that will give us a strong tool for targeted control.

Mortenson: I might jump in and mention that you and I have worked on such tracking of fields over multiple years, taking existing data from farmers' fields to help guide what you will do in the next year. There is no question there is a benefit to that. The ability

to use the spatial information shows that we will definitely be able to address at least the weed control problems.

C. Mallory-Smith, Oregon State University: Nick, it is my opinion that the companies, those producing insecticides or those producing herbicides, have embraced different cultures around integrated management or resistance management. The companies working on pesticides seem to be much more effective than the herbicide group. Do you have any comment on why that could or why it was?

Storer: I could speculate but one of the key factors is the early involvement of the EPA in insect resistance management. A lot of concerns raised from within the academic community around the risks associated with resistance development were listened to, and when the initial registrations for *Bt* crops came out, we had to develop internal programs to tackle that risk. We have been doing it now for 15–20 years with the insect traits. With emerging glyphosate resistance, you are now seeing a big change in the way we think about herbicide tolerance traits, we now are implementing herbicides with much more stringent stewardship programs than we never dreamed of implementing.

Housenger: Can I just add to that? You know getting to the resistance issue was huge in terms of going forward. It wasn't an easy thing. It wasn't something that growers necessarily supported and certainly industry was pushing to work with us on implementation. All stakeholders will be subject to the same kind of requirements in the future. I think it was a big hurdle to get over but now that it's done it will be a lot easier to impose those requirements

A. Read, Penn State: I have an observation first and then a question. The observation mostly comes from the outside, from the related issues of resistance management in the health care system with respect to infectious disease, cancers and also public health issues. It just staggers me how well organized you guys are, how much regulation there is, and how much science is going on in comparison with what is happening in infectious diseases, where we have very little control, very little regulation, very little pharmaceutical company cooperation. It is a really a staggering state of affairs. The ag sector is well ahead of medicine, which I find most remarkable. So here is my question and it comes from the title of Rick's talk this morning: All four of you seem really sure of your sciences in terms of what the best management practices are and the main challenges seem to be in terms of the regulation of them, the implementation, getting the grower buy-in and so forth, what you might think of as the sociology of the process. Is that really fair, are you really confident in your science? Are you really sure that the rotations are the best way to go? The mixtures may be wrong in some situations but not others? Or do you see that in fact there are open, unknown areas in the actual science of resistance management?

Housenger: I would indicate that we don't know. But time will tell.

Beckie: I would just add that I do believe that you know we are at a crossroads. I think the science is mature. I think we basically know what to do. We have the best management

practices developed, not perfect, rotation is not perfect. Technology is always changing: there is BioDirect down the road, but I would agree that it is the adoption by growers that is crucial. However, as they found in Australia it wasn't until they had a problem that they were forced to implement change. So when the problem gets big enough, that is when growers will be forced to, you know, go to plan B.

Mortenson: I would say that the work we are doing would benefit from a sensitivity analysis as to where the weakest points are. We need to get folks to do things cooperatively at the landscape scale, but there are still uncertainties in some of the control tactics and how effective they really are. We have some work going on where we are seeing surprising results for cover crops, in some cases we are advocating their use as the resistance management plan while in others cover crops are exacerbating the problem. More research must be initiated, but I think the bigger impact is from getting folks to behave responsibly and it seems to me that the question is how effective are these stewardship plans under different names going to be and how do we get them implemented.

R. Roush, Penn State: I have a specific question for Jack and Nick, on the corn rootworm saga, where you showed two years ago you had resistance and it seems to be caused by mixed breeding stock. How important is this problem, since it still remains the only case of *Bt* resistance in the United States, but seems to have the potential of getting away? I am wondering, from both a regulatory standpoint and company standpoint, how serious you see the problem to be and what actions are being taken to deal with it?

Storer: We felt, just like you, that when these products were first launched the resistance profile was greater than we were comfortable with. Having robust resistance programs was an important step. We work with Dow and Monsanto to modify the mode of action to try to reduce that risk. The goal is to get that product in the hands of farmers before resistance has developed to it. I think that has been largely successful. That is complemented with how best management practices are so greatly changing the way growers use the traits that they are being used in a more responsible manner and not just kind of the same year after year after year, something we all recognize has created resistance risks that we need to address. And of course it doesn't stop now. We have new products coming through the pipelines every three or four years.

Housenger: We are taking it very seriously. We took it to our scientific advisory panel for advice. We are proposing certain modifications to prevent further spread of resistance, and I think it does get back to how much growers are adopting or actually how much are they following best management practices that will ultimately determine how successful they are.

T. Shelton, Cornell University: This is directed mostly to Nick, who gave a wonderful presentation but certainly one to engender some questions. The first one would be about the credibility of the Excellence through Stewardship program and the credibility of its audits. Who is going to do that auditing? Is it an independent body?

Storer: Yes, ETS is not an industry association. It was set up by industry but it stands to the side. We are members of ETS, as are a lot of small developers and universities. We just try to get as many organizations involved in the development of biotechnology around the world. There is that broader view of what we are doing. ETS does independent audits and they provide a report on those audits back to the company. They list on their website whether or not a company has passed the audit.

Shelton: The next question might go to Jack or Nick. Would you go so far as to tell growers that they cannot plant corn after corn in a particular area where you have seen some breakdown for corn rootworm resistance?

Storer: We would work with our customers to avoid any mistakes they may have made, so we would encourage growers not to keep planting our product if it didn't work for them last year.

Shelton: Would that mean that you would encourage the lower corn price as well so they are not tempted to do this? In addition, you outlined this mostly for developed countries. What about the small farmers in India, the small farmers in South Africa you are selling products to?

Storer: This is a global program and it applies to every place where we sell *Bt* seed. The initial focus is on Latin America because of issues that need to be dealt with, but it will expand to all countries where we sell.

M. Owen, Ohio State University: Rick, according to Aaron Gasman the evolution of *Bt* resistance is becoming huge and it is getting away. I don't myself believe that we are lacking the technology to manage these issues, and looking at the surveys some of our rural sociologists have done, there was one here recently that came out of the Commodity Classic, and 98% of the growers respond that they are doing everything they can to manage resistances to pests. In my mind that is not necessarily supporting the increasing evolution of resistance to superbugs, and I don't think there is a lack of technology. What is really lacking is the ability to recognize what here recently the problem really is and that is not a technology problem. It is not a biology problem. It is not even an ecology problem. It is a socio-economic problem of scale agriculture has in trying to initiate this at the landscape level. It has to be a community-based program. But farmers do not have the time, and in the upper Midwest we do not have the labor, and right now with the low commodity prices we haven't got the money to get it done. As Hugh Beckie was saying, they are not going to do anything until they have a disaster and then they are going to wonder what happened and it will be too late. Yes, they can fix it, but now a lot of other issues will impact the rest of the production. Increased tillage, water quality issues, higher pesticide usage, and it becomes a real mess. It is, as the sociologist would describe it, a wicked problem. We know what to do. You and I and David and a lot of us have been talking about what to do from the top down for our entire careers. It is not effective. The message has to come from the bottom up. It has to be community based, and there need to be not just carrots but also sticks to induce behavioral changes. I don't see those

happening until it is too late. And I'm not sure I care, because I will be retired soon and will leave it to the younger folks.

Beckie: I just want to add that a farmer once said, "What if you guys weren't doing your jobs, how much worse off would we be?"

SESSION II: COEXISTENCE

Coexistence: The University Role

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Today I will provide a short overview of some issues I see with coexistence and the role of universities. This is my perspective as a faculty member at a land grant university.

The definition of coexistence from Merriam Webster: to coexist means to be together at the same place at the same time. Or to live in peace with each other. Given this definition, I am not quite sure "coexistence" is the word we should be using to describe what we need to do in order to produce genetically engineered, organic, and conventional crops. We may need to think about a different definition with different parameters. Here is a slightly different definition than the one Greg Jaffe used this morning, but it is pretty close: Coexistence in the agricultural sense is the ability of farmers to make a choice between conventional, organic, and GE production and still be in compliance. And that compliance could be to meet legal obligations, because there are already legal obligations in growing GE crops, or to meet certification or market standards for conventional and organic production. In this case, coexistence has entered into a different realm; it is more than saying "We are going to live together and play nice." Now regulatory issues have been added. We have started talking about compliance issues, and we might as well face the fact that we are talking about litigation issues. There is a big litigation industry in the USA that has had a great deal of input into how these crops are grown or coexist. I will talk about where universities fit in, especially land grant universities.

I will talk just briefly about two projects I am working on, and these do not even involve GE crops. This brings us back to the idea that coexistence does not just involve GE crops. One of the two projects I am involved with deals with canola production. The Willamette Valley of Oregon is known for growing high-quality specialty seed. The reputation of the seed industry is based on seed purity. There are growers who want to grow canola, and on

the other side there is a vibrant *Brassica* specialty seed industry that produces conventional and organic vegetable seed. The crossing between canola and these specialty seed crops could cause market issues, so at this point we are not even talking about GE, we are just talking about seed purity in general. How do we meet our market demands? How do we coexist? A great deal of politics also is involved, so now we have moved from science to marketing and politics.

The other coexistence issue in Oregon is marijuana and industrial hemp. Medicinal and recreational marijuana are legal in Oregon. There are growers who want to produce industrial hemp. Marijuana and industrial hemp are the same species, and marijuana growers are concerned about cross-pollination negatively impacting marijuana quality. How does a land grant university deal with an issue that has so many facets, including the fact that Oregon state law does not reflect federal law in relation to marijuana and industrial hemp use and production?

In both the canola and hemp cases, the university is responding to a legislature that wants Oregon State University to do research so a science-based legal framework can be constructed—we do not necessarily even have a choice of entering the fray.

We do have a mission, and our mission as a land grant university is founded on serving the citizens of our state through research, education, or extension. Extension really is education, but it is based on public outreach rather than formal education within the university. Part of the mission is to provide unbiased information on which to base decisions. Even though we all want to think we are unbiased, everybody has an opinion, and those opinions make it difficult to always be unbiased. Is it even possible to be completely objective about an issue like coexistence, where we are dealing with legal, social, and political issues? It is difficult for individual scientists with a specialty in one discipline to address those other issues. I can guarantee you it is not easy! Do we as a university even have a role to play? I have to say, yes, I believe we do, but we have to think about what that role is in the big picture. We are always going to be the go-to people for unbiased information.

We need to be able to participate in a way that reflects the mission of the university. We need to be able to reach out to all citizens, whether in the general public or the agricultural community, in an unbiased manner. And we have to be able to present information in such a way that we are not advocating for one side versus the other. So even if you have a strong belief on one side of an issue, you still have to come back to the data and base the outreach on that. The reality is that faculty are passionate about their research, and when you are passionate about something, it is difficult to stay unbiased.

If we look at what happens in the university, we should be thinking about the kind of research projects that will address coexistence. The first disciplines to look to are biology, ecology, and agronomy, because we need to know about gene flow, where the seeds are going, and about production. Containing all pollen movement and seed movement with the current technology is not possible. Pollen is going to move, and if GE crops are grown without concern for pollen drift, then we are going to be eating GE-pollinated crops. We have to realize that it is going to happen. I am not sure how much more data we need on this issue. Somebody mentioned today that we have not had much connection with

economics, but I think we have had a lot more interaction there than with social science or political science, I think there are many roles to be played in this area for coexistence.

When we look at formal teaching, there are many different perspectives in the university. So while some pro-GE faculty cannot accept other views, within that same university there are people who are very anti-GE who will not accept that GE may have benefits. Many perspectives are represented, and all of them become part of classroom teaching. The problem is that many faculty lack the background to discuss the different perspectives and may not have informed views. I am neither a social scientist nor a political scientist, so while I can give my scientific perspective in my classroom, I cannot necessarily bring in the other perspectives. I think we have many students graduate without really having an understanding of all of the perspectives. Students get sound bites and, of course, everybody knows that the best information is found on the internet. And that is where students are getting a lot of their information. I have to say that we as scientists have lagged on the idea that we need to be sure they are getting solid, good information on internet sites. If you look at these websites about GE issues, there is very interesting material, even if it is inaccurate. Universities have done little to compete with the misinformation. Further, at non–land grant universities, students have even less opportunity to see solid data related to agriculture. Extension is interesting because of the close relationship with agricultural clientele; at least in agronomy and horticulture, extension personnel are often aligned with a particular agricultural segment. One person may have more interaction with the growers of conventional or GE crops, while others in extension may have more of an alignment with organic growers. That unbiased position that should be taken is threatened by these close relationships. Here is an example from Oregon: A farmer grows Roundup Ready sugar beet for seed. He is very happy doing so, and it is very profitable for him. Another grower is producing organic table beet and Swiss chard seed. The crops easily cross; however, crossing in either direction is undesirable. Gene flow in either direction will impact the seed purity. Where previously there was often friction at the urban-rural interface, now growers are dealing with these contentious issues within the agricultural community. These issues make people within the university, especially in extension, uncomfortable, because the conflicts are between agriculture segments to which they may feel more loyalty.

Many faculty really would prefer not to stand in front of an audience and present a contentious issue, especially an audience that may be hostile or has a very different perspective on some of the issues surrounding GE crops or coexistence than what you might be presenting. It makes a university's administration uncomfortable, because they are afraid of what might be said. There is a feeling that no one should ever be offended. Even when the university should take a stand on an issue, often it does not because of fear of alienating citizens, including those who influence budgets. This fear-driven decision making is the opposite of doing the job right. In some cases taking a position is not going to be popular, and there will be those who are critical of any position. It is critical to rely on the data to support a position, and it is critical to be able to explain the data so that they are understandable and defendable. I have some recommendations:

(1) FOR RESEARCH

I think we should change the structure under which we do some of the research around coexistence, for instance including more of the disciplines I mentioned. Bring the social and political scientists together with agricultural and life scientists. We will still have separate disciplines, we are still doing research, but it needs to be done differently. We need to form teams with diverse skills and opinions. I must say that there is a lot of lip service to this within universities. But it is very difficult to actually make this happen consistently, because while there is funding to do one or the other, there is not much funding for interdisciplinary teams. And it is more difficult to work with a group that has diverse opinions than it is to just work within one's own discipline.

(2) FOR EDUCATION

Require all students to take genetics. That is the first and best thing we can do across the board, not just at the college level but also at the high school level, because many of the misconceptions about GE crops and coexistence are based on ignorance of basic genetics and biotechnology. Multiple surveys have been done that ask people if they want DNA in their food, and they say no. So we have to do a better job of teaching the basics of biology to the general public, starting with our students.

- Develop multidisciplinary courses taught by cross-trained teachers to provide a broad perspective rather than a narrow approach. It would allow us to have multiple people in the classroom to address issues about agriculture, whether it is organic, or conventional, or GE. There are many misconceptions about what we do in agriculture among people who are very against so-called big ag and agricultural corporations. At the same time, the broader social and political perspectives would be included in the discussion.
- Expose students and the general public to those working in the agricultural supply chain, so that they understand what their issues are. Agriculture today is not this quaint little pastime or romantic lifestyle that many perceive from old novels or movies. It is big business, and it is messy. At Oregon State University we have started to develop a speaker bureau with speakers from diverse disciplines to talk with the general public about contentious issues such as labeling, GE technology, and coexistence. The speakers represent diverse opinions that will not be expressed in the same way, but we have to come to a place where we can respect each other's opinions and avoid single-minded, one-dimensional presentations. The speakers are able to present on bigger, wider issues. There needs to be more training in how to actually face an audience, how to bring the scientific perspective to them and at the same time let them know they are respected.

(3) FOR EXTENSION

We have to help extension to serve their clientele. We have to think about how we develop useful materials. We want to explain why coexistence is required and to inform the growers of best management practices (BMPs), which must be very crop- and location-specific. Much of what I have heard today about BMPs is great in theory, but they only apply to very limited situations.

Not to insult anybody on AC21 or anybody on the Oregon governor's task force on coexistence, but these groups began with long lists and ended up with almost the same lists, rearranged, with nothing in-between that actually fixed any problems. We just keep kicking this can down the road, and now we expect it to come full circle to education and research to fix it. This is really not how we are going to find a solution to coexistence. I do not want to be the next person up here to say I believe in regulation, but we have not yet talked about that, and that may end up being the solution. We need to stop talking in circles as we have done for the last 20 years.

I will finish this talk about coexistence and the university role in it by stressing that the discussion of issues surrounding coexistence is not for the faint of heart. The issue is very contentious, and there are a lot of hidden agendas, so you can walk into a minefield—a minefield that can have a lot of negative consequences for a faculty member. Since the attacks can be on so many different levels, many faculty members simply avoid getting involved.

Speaker Profile: http://cropandsoil.oregonstate.edu/content/carol-mallory-smith

Segregating GMO Crops—Cultural and Functional Challenges

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In my world we segregate things very tightly. There are 20,000 pure line varieties of soybean germplasms. Would it be any surprise to you that some of those are better for our purposes than others? Which one do you choose? Recently we have had choices that are very different from what we had in the past. I'm a merchant. I leave the life preserver of science behind. Science gets used and abused by lots of different interests in the debates on GMO and IP. But the food shopper is my holy grail. I don't tell her what she wants. I ask her what she wants and do my best to deliver that product. The purpose of IP is to give somebody an advantage, a benefit. And increasingly you will see that benefit in market access.

We supply corn and soybeans to companies around the world. We contract with farmers to get the varieties, the hybrids, raised the way we want them, delivered the way we want. The Open Market won't deliver those to us, so we have to contract up front. The smallest unit we ship is a bag, and the largest, a vessel of roughly 60,000 tons. We secure our growers by paying a premium. I may come back to this, but I want to point out here that the market speaks with dollars. Today you are paying roughly $3.50 per bushel for conventional corn. If that were non-GMO corn, you would be paying $3.90. That could be the difference between profit and loss in farming today, easily. If that corn happened to be certified organic and IP, you would be paying $13. It is an enormous difference. That organic farmer is often netting 500 to 1,000% more than his conventional neighbor. Now, IP products mainly come in bags or containers, or through facilities that have lots of different pockets. If we have time at the end of this talk, I'll walk you through a slightly different interaction.

There is a competitive advantage for buyers. Our buyers range from a tiny tortilla or tofu manufacturer to some of the largest food companies in the world. Up until around

1994, distinctions could be visually noted. It was fairly easy to tell the difference between a waxy corn and a nonwaxy corn. But with the advent of the social distinction of GE, it became impossible to see any difference, so now we get into testing protocols. For a food supply company, contamination due to adventitious presence is now the single biggest problem in meeting buyer standards. My bias is coexistence. I don't see any alternative for American agriculture other than to meet many different demands. And I am mostly concerned about products that are raised in a way that denies neighboring growers the right to hit their preferred market. I am for continued improvement in crop production. I am not anti-GMO.

What I am really doing is managing for purity. Different standards of purity are coming into the system. So the first thing to consider about GMO is how you define the term. As Kathleen said this morning, this is sort of a bastard term. Nobody owns it. We had one well-established private definition, but now we have another definition with the USDA certification. That could be the start of a hundred definitions. I could probably argue that the reason we went with less than 50% GE as a company standard is anti-GE interests. We need some regulation to define this term. That is a national conversation. It will be a troubling conversation. I do not know what the end result will be. Zero is impossible, but we get questions from people calling from around the world, who want to be non-GE. If they insist on a standard of zero contamination, I tell them that we can't do business because that just doesn't exist.

The corn growers association agreed to accept 5%. But my problem is that I don't have a single client in the world who would accept 5%, so problems form. In Japan, for example, the official standard is 5%. If you are dealing with a Japanese food company, they are going to tell you 3%. If you are dealing with a whole food company such as a tofu manufacturer, it is 0.9%. And at the 3% level none of the food companies want to suggest they are as forgiving as their government, which shakes hands with the United States. They want to establish that they are independent, so they cut it back. The EU labeling standard is 0.9%. As for the US and Canada, we don't really have a standard. But the standard I effectively have to work with in the marketplace around the world for food companies is 0.9%.

If you go back to the development of the organic rule in the late '90s, we had about 15 competitive missionaries, all organic certifiers, all telling us their definition of organic was better than anyone else's. It was very confusing. Finally we as a community took control of that word and defined it. Since then the market has grown exponentially. The consumer has some reasonable confidence that organic is what it says it is going to be. As for tolerance levels for IP traits and cultural distinctions, we have much the same situation as for GMO. How do you get a private grain or food company to invest in a tolerance level when they don't know what it will be a year down the road? It is extraordinarily difficult.

Functional traits now become important. That raises a situation that hasn't yet become a disaster but is poised to become a disaster. I think it involves a policy mistake on the parts of USDA, the US government, and Syngenta. This is the development of Enogen corn. Enogen corn is absolutely wonderful for the ethanol industry because it comes

equipped with a lot of enzymes that take that corn starch and turn it right into sugars. If you are a starch company, what in the world would you most like to avoid? Something chewing up your product. Something chewing up your starch. So now I've got Kellogg's worried about what you are going to find in the bottoms of bowls of Corn Flakes. But what is the problem for companies like mine? According to Syngenta's own research, 1 part in 10,000 of Enogen corn ruins any other corn, GMO or non-GMO, for use as grits. One part in 2,500 ruins any other corn for use in alkaline milling, tortillas, and tortilla chips. Those are both really huge markets for the American corn farmer, for American agriculture. I can't test at the farm or the grain elevator level at either of those tolerance levels. I have to have PCR for that. So how many of you farmers want to hear, "Excuse me, can I hold your truck for a few days?" If we could get an ELISA test that allowed us to test for that level, we could test for these lower tolerances on a regular basis. But even that is expensive. One ELISA per truck would cost $30, whether it is carrying 1 bushel or 1,000 bushels. With PCR, depending on the traits you are testing, the cost can run from $250 to $750. It becomes a huge issue.

So who defines what the traits are? Private companies or a community in broad discussion? States or federal? My preference is federal, so you have the same rule everywhere. What we are seeing here is similar to what happened in a lot of other industries. When I was a kid there were two tennis shoes, the black high-tops and white low-tops. Now there must be 2,000 choices. Why wouldn't we expect the same thing to go on in agriculture? Since we added new technologies there are more and more distinctions being made. How do we go about trying to meet people's needs? We establish contract standards that we think will meet our clients' needs. We lay out segregation protocols. And by the way, when dealing with corn, if you give us a 70- to 100-foot segregation, we are pretty comfortable. With soybeans, you can give us a 12-foot segregation level and we are comfortable that we can meet the 0.9 standard. It is becoming more difficult for us to meet these standards today largely because of some seed issues.

We established verification programs, almost always using third parties and testing standards. We incentivize the producer and reward for quality and purity. Earlier I explained to you the corn incentives: from conventional corn at $3.50 a bushel to organic corn at $13. On the soybean side, conventional soybeans are around $9.50 a bushel; if it is non-GMO, around $11; and if it is organic, around $30. Again, huge differences. Now when people get an incentive to deliver you something with no more than 0.9%, they make a serious effort. The difference in price is significant. We get overwhelming, though not complete, compliance. We verify everything with documentation. We verify with testing. A lot of people think it is easy for us to get representative samples of a product like corn. But it is not easy to get a representative sample out of a truck going across the scale. It is difficult especially when we are measuring for 1 part per 1,000. Verified accurate testing to buyers' standards at the point of shipment would be a wonderful role for government. We would love to know if a shipment is going to be accepted in Japan, Korea, Taiwan, and Belgium before we invest in the cost of shipping. In grade standards that pretty much is the case. Grade standards are the basis for trading. They tell a processor almost nothing

he needs to know about the corn. Nothing about the protein levels. Nothing about amino acids, nor biochemistry. They just tell you that it is sort of yellow. So I would like to see government step in. But I know that Mr. David Shipman, who used to run the USDA's GIPS committee, doesn't want to have anything to do with certifying GMO levels. I understand why. But it would be very helpful if somebody were to do that.

On to the issue of seed. We have contamination factors coming from seed. When I ask a seed company that sold farmer X non-GMO seed what its tolerance for GMO in non-GMO seed is, this might be the dialog: "Don't ask." "No, no, no I have to ask." "We don't really know." "How can you not know? I need to know." "Well we think our average is 0.8%, but our range is from nondetectable to 3.5%." Who got the 3.5%? Who got the nondetectable? It is becoming increasingly difficult for us. Almost no one I know puts a label on their bag about the GMO level inside. So there is lots of "buying blind" going on. We can test a seed lot before planting. But how do we get a representative sample? We are asking for levels of purity that the seed industry has never responded to. The standard for hybrid purity is 95%. Now we are asking for seed standards of 99.5%–99.9%. This is a tremendous improvement. The closer you can get to perfection, the more expensive, the more difficult it becomes. One of the things we could do is buy seed from Monsanto and Pioneer in Europe, where they quit raising GMO seeds because the Europeans said they didn't want it. I understand that DuPont Pioneer has decided to give us better segregation by growing a significant chunk of their seed now in the US Pacific Northwest, where the main air flow comes from the west, so the closest corn upwind is Hawaii.

So we have these two possibilities, EU purchase or more extreme domestic isolation. We have farmers who have protocols for cleaning their equipment, third-party inspections, testing during production, and buffers for purity. Post-harvest you have a lot of cleaning, testing of inventory before delivery, testing each load on shipment and subsequent to shipment at the final destination—there are many choices. With ELISA we can go down to maybe 1 part in 400. The benefit of ELISA is that it is quick and relatively inexpensive. PCR takes more time than you have if you are to keep the flow of commerce going, and it is tremendously more expensive. The cultural standards can all be addressed by the 0.9% rule. As for the functional standards, I'm guessing the buffer area needed to avoid 1 part in 10,000 would be a mile. One acre of high-amylase Enogen corn will commercially exclude the surrounding 2,000 acres from producing corn for grits. That lends itself to private zoning in the Midwest. That is not the way I want to organize agriculture. This could be avoided. You could put a marker in that amylase corn to allow those of us who care to separate it out. How long does it take to put a colored stripe in corn? About two generations. How many generations can you plant and raise in a year in Hawaii? Three. Is that too much to ask of the system? To put a marker in something that could be this disruptive? I don't think so.

This morning a lady asked about organics and process definition. There is a wrinkle here. Organic standards are process defined. I think that was done well, skillfully, and diplomatically. This is pretty much what the rule says about GMOs: Crops raised according to the organic rules are organic. They are to be raised without using any GMO inputs. There is

no testing required to prove or disprove that the crop is organic. There is no defined level of adventitious presence of GMO that negates the organic identity. But there are today certified organic crops that are no longer marketable because almost every food processor sensitive to the market wishes to avoid GMOs. These buyers require crops to be both organic and non-GMO. They define non-GMO as having less than a defined level of GMOs. So the real market situation for an organic farmer is that he starts towards a really good market. With too much GMO content, we have to divert him to another market, and those diversion markets are becoming fewer and farther between. The first market was close to his farm. The next market might be 1,000 miles away. Logistics become a significant problem. So the potential loss to an organic farmer from a substandard market could be $9 a bushel on corn; $9 a bushel on 150 bushels an acre, that is $2,025 per acre. Are there some who lose? Yes. My company is one of the very few that is willing to share our data on rejections, with all the personal information stripped out. The percentages that we reject allow some calculation of national losses. These estimates are not perfect. But I think they are reasonable.

What is the vision for US agriculture? My goal is that US agriculture must support farmer choice and protect farmers from being market-dominated by their neighbors. You can do that if you use buffer strips to segregate GMO cultural traits from non-GMO fields. Unless there is some responsibility for two farmers to talk, they probably aren't going to do it. But if there is a responsibility, then they will talk and may coordinate crop rotations so that they need no buffer at all. But how at the same time do we support the farmer who wants to plant GMO crops and serve GMO-accepting markets? How do we support the technical development of crops without disrupting markets and ruining markets for neighbors?

How can we balance and respect these conflicting values? I think we have to acknowledge when a significant market distinction such as GMO merits labeling as a coexistence solution. There is obvious popular interest in getting GMO/non-GMO labeling. So I would like to see non-GMO labeling. It means you have to just define what the label means, what level of GMO presence is acceptable in a product labeled non-GMO. Such labeling would not be mandatory. I think that voluntary labeling addresses the consumer's right to know. Mandatory is unnecessarily punitive to other people in the ag community with whom we need to coexist, cooperate. I think we have to define "non-GMO" as meaning "less than X content." What is the value of X? I don't really know. And we have to enforce truthful labeling through FDA or USDA. I think there is tremendous credibility value in USDA services. It is absolutely wonderful on an international basis. I think it should be the same at home. I agree that farmers don't have the right to damage their neighbors' market choices. You can drive this to an extreme. And most arguments driven to extreme collapse. But if the segregation requirement is reasonable, and we get a reasonable tolerance level, then I think farmers on both sides of the GMO fence have a responsibility to cooperate. That can be enforced through access to insurance, payments for conservation, lots of ways. On seed approval, market disruption as well as safety needs to be considered for new traits and new commercial seed groups. The time to define weed status is also

during the approval process. For less disruptive traits, appropriate buffers are okay, but when a new trait comes into commercial availability, we should take a look at it as a community and determine the disruption factor. I think we should require appropriate segregation buffers to be included in contracts between a seed provider and a farmer so that all parties understand that they are participating in this industry. The potential benefits minimize the expense and conflict over labeling. I think the arguments over labeling will continue and voluntary labels will ease the controversy over introducing new traits. If I felt more secure when a new trait was implemented, there would be a lot less resistance from members of the community that I now have to engage. We can minimize resolution via tort law and class action—a terrible way of making policy. But it will hammer out a policy. I think we'd satisfy many who want a reliable label by voluntarily using labels, and it would support US farmers of all stripes as disciplined suppliers to the world. The world looks at the United States right now and says, you people can't control your seed supply. You are being rejected by China. Look at you, you let Starlink get through, you let something else out. This didn't do anything good for our credibility in the world.

Speaker Profile: http://www.clarksongrain.com/about-clarkson/

Coexistence in the Oregon Seed Industry

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West Coast Beet Seed Company was incorporated in Oregon in 1940 by numerous shareholders who had determined that the Willamette Valley of western Oregon was the best location on the US West Coast in which to overwinter sugar beet plants for seed harvest the following summer. Although other areas grew some seed, by the 1980s essentially all sugar beet seed for the US was produced in the Willamette Valley. Today a large percentage of sugar beet seed continues to be grown here.

As for all seed crops, and there are many in Oregon, genetic purity is an essential quality attribute. Production of sugar beet varieties has always included standards for distance between sugar beet fields, usually known as isolation distance. Seed production of other subspecies of *Beta vulgaris*, primarily Swiss chard and garden (red) beet, also began in the 1940s. This required additional consideration of isolation distance. So, for about 75 years all beet production in the Willamette Valley has successfully coexisted.

Over the years, growers and seedsmen talked to each other about maintaining adequate isolation distance between crops that could cross-pollinate. In 1980 this informal communication system was formalized through the incorporation of the Willamette Valley Specialty Seed Association (WVSSA). Initially, the primary function of the association was to map competing seed crops, using pins placed on a physical map to identify and regulate isolation distances, for the mutual benefit of members. In recent years a physical map has been replaced by an electronic web-based map, but the process of adding place markers to represent fields continues to be referred to as pinning. This model has been highly successful and has drawn worldwide attention, as evidenced by the accelerating expansion of the industry since incorporation. Currently, there are 41 active members.

Because of thoughtful production guidelines that have been written and revised as needed over the years, disputes are uncommon. When growers or seedsmen find them-

selves in conflict over any seed production, rules of arbitration are applied. In 35 years, arbitrations have averaged fewer than one per year and have been 100% successful at resolving conflicts. One party won and one party lost, but in all cases all parties have agreed to voluntarily abide by the arbitration decision. In recent years the association has mapped up to 1,200 field locations, many of which involve competing crops. In the case of our company alone, up to 75 growers have received arbitration.

When our company began production of the first deregulated genetically engineered sugar beet seed with small plantings in 2005, our production area already was utilizing world-class guidelines that allowed a seamless transition to high standards for genetic purity for yet one more trait. By 2009 the US sugar-processing market was using sugar beet seed that was resistant to the herbicide Roundup almost exclusively. During that same period, the production of Swiss chard and garden beet continued locally and, if anything, increased relative to recent prior years. All of these beet types continue to successfully coexist. The genetic purity of each is similarly important, and stray pollen or seed moving among beet production areas is a shared risk.

While no system is flawless, that of the WVSSA has existed and continued to develop for the mutual benefit of association members for over 35 years. The WVSSA has one or two members who produce exclusively organic seed. The association has at least one other member who produces some organic seed, along with conventional seed. We have a membership category for small seed savers that would like to participate in our mapping system but do not qualify for association membership. West Coast Beet Seed Company has at least two growers who produce GE sugar beets in the same farm operation that produces non-GE conventional crops and organic crops.

Pinning regulations of the WVSSA continue to develop over time, with occasional changes reflecting new science, implementing additional experience, or addressing new issues, crops, or previously unforeseen problems. Regulations are built upon the Statement of Purpose in the bylaws of the WVSSA. Included in the purposes of the association are these programs: Seed Quality Management, Education, Pest Mitigation, Production Area Sanitation, Seed Quality Risk Mitigation, and Specialty Seed Research.

Pinning regulations must be adhered to as a condition of membership, including but not limited to:

1. Rules for establishing a crop isolation with either a spring or fall deadline.
2. Maintaining a pinning priority related to member contracts year to year with the same grower.
3. Arbitration of disputes.

Isolation distances are detailed for species of *Allium, Beta, Brassica, Cichorium, Cucumis, Cucurbita, Rhaphanus, Spinacia,* and *Umbelliferae*. Flower seed production needs to be pinned, along with that of "other seed crops." These latter types of production are likely to require discussions among members. Distances of separation range from one to four miles. The regulations are strict but do include exceptions for two members who mutually choose to decrease an isolation distance or who agree to yield a pinning priority for one year to the other member and contracted grower.

In addition to association pinning regulations for genetic isolation purposes, the WVSSA has adopted its Stewardship Policy to further establish a platform for coexistence, as well as a definition of stewardship terms. All are available at the WVSSA website (www.thewvssa.org), along with bylaws, forms, industry links, and descriptions of the growing area.

The Stewardship Policy features the following objective and five core goals:
Objective: Anticipate the release of traits from biotechnology with a proactive set of policies designed to support coexistence, defined by the USDA Advisory Committee on 21st Century Agriculture (USDA AC 21) to be the concurrent cultivation of conventional, organic, identity-preserved (IP), and genetically engineered (GE) crops in keeping with underlying consumer preferences and farmer choices.

1. Maintain a vibrant Stewardship Committee that is proactive on biotech changes in Oregon agriculture.
2. Develop a reasonable threshold of tolerance for each biotech trait so that zero tolerance is not forced upon the industry.
3. Engage trait owners in stewardship that complies with and supports WVSSA policy.
4. Engage Oregon growers in the rationale for a Stewardship Policy for the Oregon seed industry.
5. Network with other organizations, associations, and agencies that can provide strength, support, and sustainability to the WVSSA Stewardship Policy.

The Oregon seed industry has been challenged to define "biotechnology" with a meaning that captures the variations in definition among regulators and markets. In lay terms, our federal government regulates the crops and traits of biotechnology if the Department of Agriculture can identify a potential plant pest, if the Food and Drug Administration has a food or feed safety concern, and/or if the Environmental Protection Agency sees a pesticide safety issue. Market definitions, however, are not limited to regulatory stipulations. Markets or some customers within markets can choose to limit commerce in products derived from deregulated biotechnology and also can limit nonregulated products that may appear to have come from biotechnology. An example of a nonregulated trait is the herbicide tolerance in the Clearfield Production System for wheat using Beyond herbicide. This trait was developed with chemical mutagenesis and was never regulated by a federal agency. Interestingly, this type of herbicide tolerance has been widely accepted as non-GE. Yet a comparable herbicide tolerance yet to be released in turf grass appears to be unacceptable in some markets and certainly is unacceptable to opponents of biotechnology. The trait was developed with a gene gun and has a USDA determination of "nonregulated."

Seed suppliers cannot control market or customer definitions of products. Consequently, the Oregon seed industry has attempted to encompass perceptions, as well as government definitions of regulated crops or traits, by applying the phrase "unconventional plant breeding" to products that could come under "biotechnology." To date, unconventional plant breeding is defined to include the following:

- *Genetic modification.* The production of heritable improvements in plants for specific uses, whether through transgenics, cisgenics, or more traditional methods. Some countries other than the United States use this term to refer specifically to genetic engineering.
- *GMO.* An organism produced through genetic modification.
- *Genetic engineering.* Manipulation of genes by introducing, eliminating, or rearranging specific genes using the methods of modern molecular biology, particularly those techniques referred to as recombinant DNA techniques.
- *GEO.* An organism produced through genetic engineering.

The WVSSA is one of two major seed associations in Oregon. The other is the Oregon Seed Association (OSA), which was chartered in 1969, has 49 active members, and is organized primarily around grass seed crops.

Like the WVSSA, this association has adopted a stewardship policy with defined terms to establish a platform for maintaining voluntary coexistence. The most likely new application of coexistence at this time is the potential for herbicide-tolerant turf grasses to enter the market. Developments in Kentucky bluegrass and tall fescue are not in the market yet, but they will not be regulated as potential plant pests under USDA rules. Nonetheless, there is industry concern because many markets do not distinguish between regulated, nonregulated, and deregulated products of "unconventional plant breeding." Consequently, these herbicide-tolerant grasses will be unacceptable in some markets.

In grass seed production, the current isolation standards focus on distance separations related to Oregon State University crop certification, and these are widely accepted. However, due to relatively high crop production acreage in the Willamette Valley, close proximity of fields, and windblown pollen, these standards would be inadequate for markets with low or no tolerance for traits assumed to come from biotechnology. The OSA will be working in the next year or two to develop further policy and practice to guide association members as product launches near.

Farmers have coexisted successfully for generations and nearly always resolve conflicts with a neighborly solution. After all, land cannot be relocated, and eventually neighbors must cooperate in order to coexist. With the introduction of modern biotechnology to agriculture, there seems to be an unprecedented challenge to successful coexistence. A combination of some consumer attraction to a more localized food supply with less or no reliance on the technology of "big corporations" and activism in opposition to modern farming practices and technology has fueled conflict. Not just in Oregon, but especially in Oregon, ideological opposition to biotechnology has resulted in a push for political solutions to ban or constrain biotechnology.

In 2013 the Oregon Legislature preempted local initiatives to ban or restrict biotechnology by establishing regulation, if needed, with state government. An exception was made to allow a county measure already in process to proceed to a vote. In May of 2014, Jackson County in southern Oregon did pass a ban on GE crops. The county

ordinance subsequently entered litigation when two farmers sued for current and future crop loss in alfalfa production. Since then, Benton County, home of Oregon State University (OSU), has placed a GE ban on the ballot. Supporters campaigned for it as a local food ordinance, but it was written very broadly to exclude all GE activity, including research at OSU. The language also gave Benton County constitutional and legal authority over state and federal governments. It was defeated by a large margin on May 19, 2015. Had the measure passed, it would have violated state preemption law and would not have been enforceable unless state law had been reversed by the legislature or by a court decision. Furthermore, the measure would have been unenforceable for many reasons related to state and federal law. Supporters agreed throughout the campaign that it would have gone straight to court.

In the current Oregon legislature, several bills have been presented that would authorize the state to regulate agricultural biotechnology for market reasons. Some proposals require or allow the state Department of Agriculture to create districts that limit or exclude GE traits and crops. Other proposals allow citizen petitions that lead to a similar outcome. Proposals have included requirements to report GE seed transactions by area of the state and to make public maps of transactions available.

A legislative work group with diverse membership has recommended a far less restrictive bill that is still under consideration. This bill offers rules for mediating a dispute between parties with a complaint around coexistence by requiring a conversation seeking friendly resolution.

Government intervention concerning ideological differences in modern agriculture entails numerous challenges. At the core, however, the challenge of coexistence among producers of food, feed, and seed finds the non-GE minority trying to exert their will over a majority that either favors biotechnology or favors modern agriculture in general. Since the population of our country is largely urban, with consumers mostly disconnected from the farm, they have a significant opportunity to establish a message opposing biotechnology and modern farming. This includes efforts to gain political advantage among legislators or local government officials, to litigate, and to persuade through social media. Few state legislatures are populated with more than about 10% of legislators with natural resource experience. Americans in general are not knowledgeable about agriculture or other natural resources and can be convinced to believe one-sided messages. Consequently, an activist minority views a strong government role as the surest way to achieve ideological goals, though most activists seemingly prefer less government otherwise.

Government regulation of agriculture for market reasons is likely to introduce many new conflicts and uncertainties in an effort to ease ideological conflict. Several illustrations follow.

1. Government restrictions mean new government authority to control crop choices. In a matter of a few years this would effectively eliminate the WVSSA, a very successful organization built around voluntary coexistence. The economic damage to businesses and the state from a disorderly transition from a private to a public system of coexistence could be high and lasting.

2. Implementation of restrictions will not assure perfect coexistence—that is, zero adventitious presence. Further exclusion will be suggested as a logical additional step, and conflict will persist or even increase. What will be the standard to reduce conflict if one party demands zero tolerance?
3. How will a second layer of conflict be accommodated in an existing coexistence agreement? For example, suppose a GE crop is allowed to coexist with non-GE counterparts because the trait in question has a nutritional benefit. Now, suppose that same crop is stacked with a herbicide-tolerance trait. Will the coexistence rules change?
4. Rules to determine how to best protect competing markets and crops are difficult for even experts to devise. Relying on a government solution will greatly reduce and probably eliminate the participation of most private sector experts.
5. Voluntary coexistence is nimble compared to legislated coexistence and more likely to respond quickly to changes in markets and products. Oregon could legislate regulations that create an economic disadvantage compared to other states.
6. If and when districts, control areas, or production zones are created, many new borders will be invented. Growers on either side of a border will find it more difficult to coexist. Many growers will farm in multiple areas with differing restrictions. Rules for reviewing the purpose and value of a district will need to be established, as well as rules for modifying the district if a change is warranted. What constitutes justification for a modification? Actual market? Potential market? How much justification can be objective, and how much subjective argument will be allowed?
7. Voluntary coexistence is self-regulated for compliance and works well when mutual benefit is maintained. This coexistence is designed to meet competing market objectives, but without guaranteeing perfection. Government solutions to coexistence will likely lead to an expectation of financial protection from harm if success is not achieved to perfection.
8. Government-regulated coexistence is likely to trend toward a general approach. For example, in a control area that bans GE crops, would it be possible to secure permission to produce a GE crop that is self-pollinated or a GE hybrid in which the pollen parent is not GE and the seed parent is GE but male sterile?
9. Government restrictions are likely to remove one or more crop choices from growers who may have had a long history of producing a crop that becomes restricted. Many states have right-to-farm legislation that appears to protect growers from this outcome.
10. If farmers or citizens feel that government has overreached, what is the appeal process? What "experts" are called upon, those with agricultural experience or those who have ideological objections, suggestions, or demands?

11. Who pays for regulation? "User" fees will be very unpopular with growers who lose crop choices. The general public is unlikely to comprehend regulations and is likely to object to funding them through new taxes.

Unless ideological differences can be overcome with education, acceptance, tolerance, and a will to coexist, there will be ongoing political and legal battles in Oregon for years to come.

Speaker Profile: Greg Loberg holds degrees in agronomy from the University of Minnesota (BS 1977) and Iowa State University (MS 1979). In 2007 he joined West Coast Beet Seed Company. Previously he worked in sales and marketing of seed treatments with Gustafson and Bayer Crop Science and from 1981 through 1988 in a diversified vegetable and grass-seed production company in Oregon.

Coexistence

Q&A

MODERATOR: CAROL MALLORY-SMITH
Oregon State University

M. Kahn, Washington State University: We also have a paying program, and what maintained that for many, many years was that farmers could make about ten times as much money growing seed on that land as they could growing the crop itself. If you produced spinach seed it brought in ten times more than producing spinach, so neighbors got together and agreed to yield their choice of crops to work together, because they could make so much more money that way. Lynn's talk emphasized the fact that there are some very significant price incentives to being in some of these labeled categories. There is a price incentive to being organic. There is also a production incentive to doing genetically engineered crops, and in the case of beets it was shocking to me how fast genetically engineered beets took over the market. In less than three years it went from 0 to over 90%, which is simply unheard of in American agriculture. Some of what brought that about was that there were not such precise standards. That occasional squash plant that was straightneck instead of a crookneck wouldn't take you out of the market. As long as most of your seed was what it said it was going to be, it was fine. I wonder if a 0.9% threshold is something that various people can live with. Lynn was giving us a range, but at what point do these neighborly agreements break down in the face of regulation, which is where I think you guys were going.

Clarkson: With respect to soybeans, that is not really a problem. With respect to corn, neighborly agreements about a 0.9% threshold may have a limited life span, because it hasn't been getting easier to get the 0.9% standard, it has been getting more difficult as new traits are added, and as the germplasm selection becomes somewhat more tainted. It is tremendously difficult for seed companies to keep adventitious presence out of their breeding stock. I don't know how long 0.9% is sustainable with respect to corn.

M. Kahn: A quick follow-up question: Is there a danger in setting a standard and then finding that that number can't hold?

Clarkson: Of course.

Loberg: Could I add something here. The answer to this question lies in something I mentioned briefly, namely treating all genetically engineered crops the same, regulation without a lot of layers and rules. So why would you, for example, treat a wind-pollinated sugar beet, a crop that requires an isolation in either direction—from sugar beet to Swiss chard and from Swiss chard to sugar beet—of four miles. Four miles is a long way, but in sugar beet seed production we can achieve that. It does not guarantee 0%, but it gets us close. On the other hand, why would you require four miles for an insect-pollinated cabbage seed? The insect is very, very unlikely to go that far. And corn pollen goes ten feet, or a very short distance. I am exaggerating a bit, but the point is that the fear of government regulation is that it will be blanketed across all genetically engineered crops without differentiation.

Clarkson: It has been a general, a very general broad-based sketch for all GMOs; they are judged the same in spite of different implications, and you are going to see that on a national level.

G. Roth, Penn State: I have talked to some of our local industry people interested in moving toward GMO. They are somewhat worried about liability, about ending up supplying grain that they thought was non-GMO and it turned out to have GMOs in it. I wonder if Lynn or the rest of you could comment on the history in the industry of producers suing each other over who caused the contamination in the product, or can you mitigate that with your careful testing program?

Clarkson: Let's talk about corn, because that is where the problem comes up most often. The farmer liability with respect to his contract ends when he brings it to where we sell it. We assume the liability based on testing at that time. We have never yet known a farmer to sue a neighbor over contamination. We test every load of corn that comes through our gates, and it goes into computerized records so that we can look back for years and see what load was rejected and on what the rejection was based. In the first 10–12 years of the GMO world, we were rejecting maybe two or three truckloads of corn per hundred. Tolerable—painful if it happened to be your truck, but it was tolerable. That has approximately doubled in the last two or three years, and much of that comes from seed sources rather than from cross-pollination. So the issue on corn I was talking about has yet to hit, of course, but we don't have very many rejections here because we can't detect it. We as the supplier have passed the problem on to the processer, and none of us will know which way it goes until that problem actually happens, because it's so small. But if you look at organic crops, because organic fields tend to be smaller than non-GMO fields, the rejection rate on organic is just about twice what it is on conventional corn, but it's still less than 10%.

M. Owen, Ohio State University: Just out of curiosity, do you still get occasional Starlink showing up?

Clarkson: Thank god, no.

T. Harding, Lehigh Valley Growers: I was curious, today the one thing I haven't heard, which I have heard thousands of times in other discussions, is the whole point of the ethics. I was wondering if you had an opinion about the ethics of biotechnology in general. At a conference I attended recently in Europe the question came up, not by left-wing crazy people but by people who are real good scientists, saying what about if we have a total crop failure? What happens if all of our crops fail in spite of the steps we are taking? By the way, I am very impressed with what I have heard today. Have we discussed that? Have we really looked deeply enough into how we as an industry, meaning all of us here in this room, can make sure we don't have further problems with resistance? Maybe we in America should put more of the precautionary principle to work here. From my point of view, labeling is not the direction to go. I have lived with tolerance levels for a long time. They are targets, and we haven't even reached the segments of the vegetable growers, small fruit growers. These are serious issues we are talking about, food and the sustainability of it. Are we talking about the ethics of this? Are we talking about precautionary principle reaching deeper into the approval process, and are we really thinking not only about what the marketplace wants, but about the sustainability of our farms and the liability of our agriculture system?

Loberg: Carol is going to get the last word on this. I think the challenge from my perspective is that ethics change with context. I was telling someone just before we came to the front here that I have a niece who just loves a local food supplier, so much so that she is on Facebook all the time touting the local food supplier. Good for her! Locally grown and fresh, and I'm not against it, but finally I got so tired of listening to her and I said "Well, how is that local food supply thing working out in Africa?" Not too well. So when it comes to ethics, the context becomes important. Starving to death is not a very good thing to push onto people when we have the capability of feeding them. But at the same time the ethics of sustainability must be considered.

Mallory-Smith: I agree with you, but I don't really think that the Roundup-resistant weeds are really affecting sustainability in agriculture. We had resistance before we got Roundup resistance. We would have it even without GMOs. It is a reality of the conventional agriculture system. I think the ethical discussion begins when you start looking at possible actions and then ask if we should take them. And those are traits beyond what we are currently talking about. We are not as comfortable with some of the emerging technologies as with the ones we have been using all along, and we are wondering if they are going to have the same kind of repercussions. There are some ethical questions here. I think it is important to have transparency in our regulatory system, which is not currently the case, and we must be able to evaluate the data, most of which is not available to the general public. Having said that and wanting transparency, I will definitely agree with Greg that using the Noxious Weed Law to look at these crops is not the way to go. We started out with the bad regulatory system of trying to scrunch GE crops under APHIS rules for pest management. Those rules were not written for this technology. And now

we are trying to take them and use them to do the same thing all over again. So unless these new crops actually are weeds and invasive, they should not be called so. They are crops. We should not take this route just because they are genetically engineered, even if the regulatory authority gives you this option. That would just mean making another bad policy decision, and I'm afraid we are heading in that direction.

Clarkson: The range of values and the discussions always get so murky that I am waiting for a life jacket. Roughly 30% of the food produced in the States seems to be wasted. Roughly 30–40% of the food raised in India seems to go bad during storage, before you can even use it. I get lost in all that murkiness. I remember talking to the head of one of the food co-ops that provides food for roughly 6 million families around Tokyo during a Monsanto tour that lasted four hours. I asked, "Dr. X, how many years have you been doing your research?" She told me that she had worked on this for 14 years, that she really admired my absolutely world-class science, and that she encouraged me to continue. She told me, "If this were our IP we wouldn't use it until a generation passed. That's 30 years. Please call me in 16 years. I could be your best client." So that is my client talking. That is your client talking. And it wasn't a dismissal. It was a deferral. I think that is the major difference. As far as noxious weeds go, that is not a very good vehicle. It is focused on market disruption, and most of us in agriculture are not so much concerned if the issue is whether it is GMO or non-GMO, it is a market disruption issue. Can we manage the technology and have both? I think we can, but I don't see it happening voluntarily.

T. Harding: I want to follow up on the issue of the land grant systems and our responsibility for transparency. It is important, because the land grant system is so important to all of us as growers. With regards to Africa I will tell you that the work I have done in Africa indicates to me that the small producers feel very differently where the sourcing of the seeds is concerned and how they continue to the next generation. These are important issues, so maybe the dialog should be from an ethical stand point. We need to have a fully transparent dialog and we all need to listen to each other. Today has been a very good discussion, but I don't think this is taking place everywhere. Certainly the committee Lynn was on seemed to miss out on that discussion, and I sometimes wondered if they were all in the room at the same time.

R. Hardy, NABC: I want to make a comment on bioethics. Back in the mid-90s NABC established a federal initiative to educate our university members on bioethics. It was a one-week immersion course for 20–30 professors each year. That program ran for several years, until the interest faded, and we felt at that time we had saturated the market. This was around 2004. We have also had noted bioethicists on the programs for NABC meetings, so we have been quite involved in that area.

D. Benfield, Ohio State University: I have heard all afternoon that we feel like we can handle the technology. We feel that the technology is moving forward in positive ways. But as an associate director in the [Ohio] Experiment Station and a college administrator, I wonder what the academic institutions are missing, besides knowledge that might be

beneficial in this whole gamut, in this arena of GMO and genetically engineered crops, in terms of public acceptance or helping to promote that public acceptance.

Mallory-Smith: I don't know exactly how to respond to that because I'm not sure that as a scientist it is my job to drive that acceptance. I think my job is to make sure people have the right information about it and people have the right to make their own choice.

D. Benfield: I will rephrase: Are we as scientists providing the right information?

Mallory-Smith: No. I think we might be providing accurate information, but we are not providing it in the best way, especially when we still have people who say they don't want DNA in their food. So obviously we have failed as educators. And I think we have failed with education about resistance management, too. We have not delivered; or Mike, do you think you have delivered it correctly?

M. Kahn: No, I agree with you entirely.

Mallory-Smith: We claim to be the educators at the university, but we have failed. So how can we deliver the message and make sure that it is understood? I am talking about resistance, for which we haven't had economic drivers on the farm. As far as public perception, we haven't had the web presence or other tools that would actually convince people that we are delivering accurate information. We certainly don't have the tools to compete with the wild stories, and we don't come up with our own wild story about why it is not as posted on Facebook and still sound credible. I think we are credible, but the public doesn't really care what is credible. They would rather read something interesting. So maybe we are just boring?

Loberg: I want to make a quick comment, a short story on the Benton County measure, which is a very broad and damaging measure to the county and to Oregon State University. One thing I found out during the campaign against that measure is that there is a single researcher who is responsible for a $2,000,000 program in medication of ALS, Gehrig's Disease. I had no idea that Oregon State University was world renowned in ALS research. To test his drugs, he uses genetically engineered mice, predisposed to be susceptible to ALS. When I heard that, I wondered who in Oregon, who in Benton County knows Oregon is known for ALS research? A lot of people don't know that. So I think there is room to just tell the public the big picture stories. One of the problems I have personally is that I know too much and I want to tell everybody too much. It is a problem for scientists in general that we know too much, and that is not what works on social media. There they don't say too much. They just say a little and let you figure it out, and they don't care if it is inaccurate.

Mallory-Smith: I agree that it is more about getting sound bites that resonate with the public. In the case of this particular measure, I felt the university should have taken the lead. The university should have stood up and explained the bad results that would come from it. But the university administration is very nervous, and they didn't even take a stand on this. They did some underground maneuvering, but they didn't state that Oregon State University is against this. But sometimes you have to find ways to have impact, and

we just have to learn how to communicate with the public. There are training programs trying to work with scientists to do that, but apparently they are not working fast enough.

Clarkson: Many in these industries are used to their clients being growers, and that would be all the interaction they would need. Sometime around 2000, consumers pounded the table and said, "I'm not happy with the food system and I want to be heard." And that is an entirely different perspective. So we might get sound bites out there that are correct, but the consumer doesn't understand them. Here is a case in point: Sometime over the last six months a study came out that in mother's milk in the US you find ten times the level of glyphosate as in mother's milk in Europe. Now, I don't know whether that is true, and if it is true I don't know if it is significant. But in the market that I deal with, I absolutely know that that was a significant story, and I have already had to make sure there is no glyphosate in breast milk. It is a difficult issue, but the market pulls some things through and tries to push others through. Right now we have the organic market pulling things through. It is asking for more and more according to our studies. You get companies who are selling into the stream of commerce, but they are not selling it to the consumer. They are selling it someplace else in the supply chain.

S. Fleischer, Penn State: A few years ago I was teaching a class on issues of biotechnology, and the only comment I want to make is that in the resident part of the land grant system you have a great opportunity. After fine-tuning the design of this class three different times, I approached it as an exercise in critical thinking rather than trying to deliver information. It was all about students talking about how they are approaching problems. We developed a protocol for this and went over a lot of content about the different components and found this to be a great opportunity for teaching critical thinking. I thought we could then move on to the science and STS type programs, but then Penn State got rid of the STS program. While this program has not moved forward, it was a great opportunity to teach critical thinking.

M. Irey, United States Shared Corporation of Southern Garden Citrus: We are probably one of the largest farms east of the Mississippi. I think to a certain extent you are too hard on yourselves about failing as educators. I think you are just reaching the wrong group. Everybody here is either an aggie or is from a land grant institution, and there are undoubtedly people who need to be reached in that population, there are many people who are not part of the agricultural system who don't have a clue where food comes from. All they know is that it comes from the grocery store. We are in a very environmentally sensitive area and found that it is helpful to just bring consumers in and show them our operation. A different kind of education needs to be done, not necessarily what you are used to.

Mallory-Smith: I agree with you. I speak with many general public audiences who do not have a science background and I know I have an impact, but I am still only reaching small segments of people, those who have an interest in learning.

M. Irey: But it's one less group that is going to badmouth it.

D. Mortensen: I appreciated the comments of the previous speaker and want to follow up on them. I am also at Penn State. I couldn't agree more that we are reaching the wrong audience. And the idea that a website or a pamphlet or a magazine article is going to solve the problem is really naïve.

Mallory-Smith: It was a YouTube.

D. Mortenson: Whatever. We have a systemic problem with the education about the food system, and my view is that the local foods movement is actually one of the best places for teaching opportunities in a very engaged nonagricultural community. I would like to hear your reflection on this comment. I think that is at the core of much of what needs to happen instead of surveys about DNA, etc. I also second Ralph Hardy's comment about training in bioethics. It is my view as a scientist that the science community is very arrogant when they claim that "we'll tell you what the science says." This is very naïve. I participated in an ethics panel here in September right before the deregulation of the 240 crops, and people were sitting in the aisles who wanted to hear this, mostly non-ag college folks. We were all asked to read Bernard Rollins's *Ethics in Science* before we participated, and it is very helpful to remind us scientists that we bring a great deal of passion to subjects we choose to study, the way we choose to occupy our time, and the work we do. We need to keep reminding each other that there are biases built into all kinds of things, whether we're teaching as scientists or consumers.

SESSION III: TRADE AND MARKETS

Trade and Markets for Genetically Engineered Crops: A USDA Perspective

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I am pleased to have the opportunity today to speak to you as part of this panel about the complex issues of trade and markets for genetically engineered (GE) crops. I speak from the perspective of the United States Department of Agriculture, which has multiple roles in the agricultural sphere that bear on these issues. These range from research to regulation to rural development to marketing and impact the entire food and feed production chain.

USDA supports the safe and appropriate use of science and technology, including biotechnology, to help meet the agricultural challenges and consumer needs of the 21st century. USDA plays a key role in assuring that GE plants and products derived from these plants are safe to be grown and used in the United States. Once these plants and products enter commerce, USDA supports bringing them to the worldwide marketplace.

In a larger context, USDA provides support for all agricultural products and production methods. That means we also support organic and identity-preserved non-GE production as well. It is important to note that these identity-preserved methods yield high-value products for which there is consumer demand. This in turn has led to new economic opportunities for farmers, which are important for rural revitalization. Given the fact that the average age of US farmers in 2013 was 58.3 years, bringing new farmers into agriculture is important for the health of farming communities and therefore important to USDA.

These realities, combined with the complexities of coexistence of biotechnology-derived crops and non-GE/organic crops and the continuing public debate around GE crops, mean that it is important to consider GE crops and crops produced using other production methods as interrelated components of our overall agricultural environment.

Other speakers have already talked about the enormous adoption of GE crops here and their increasing adoption around the world. But it is important to note as well that lack of confidence about GE crops affects our domestic markets and affects all of agricultural trade. And therefore issues around coexistence in a US context contribute to domestic debate on GE crops, and these issues are of great concern to USDA.

The United States remains the world leader in the development and commercialization of plant biotechnology products. Our regulatory system, which has been discussed at previous NABC conferences, employs science-based decision making, addresses stringent legal requirements, and incorporates public input as well.

Other countries are also making significant advances in the research and development sphere. Notably, Brazil has become the second-largest producer of GE crops and has developed its first domestically derived GE products. China—though it poses difficult biotech trade issues for the US, has slowed commercialization of some key domestic GE crops, and is experiencing some anti-GE sentiment among its citizens—is nonetheless committed to biotechnology development. Biotechnology is designated as a strategic emerging industry in China. While the total amount of Chinese government expenditures on biotechnology is unknown, it is believed to far exceed public sector investment in biotechnology in any other country, including the United States.

USDA's overall approach to trade involving agricultural biotechnology-derived products has several key features:

- Support for science-based decision making
- Vigorous support in the international arena for our regulatory decisions, including specific engagement with markets where we have issues
- Continued international engagement in key multilateral forums
- Partnering with like-minded countries to develop coordinated approaches toward major trading partners that are not making science-based decisions
- Working with key target countries just considering their domestic approaches to GE crops to help them establish science-based decision-making systems as well as to support them in their development of technologies specific to their own agricultural problems

In terms of market problems we continue to face around the world for US agricultural commodities and products with GE content, clearly the European Union (EU) and China present our greatest challenges. In brief, agricultural biotechnology remains a sticking point in our trade relations with the EU despite years of engagement. The case the US successfully launched with our co-complainants Canada and Argentina in the World Trade Organization in 2004 has not resolved what are essentially political issues in the EU around the use of biotechnology in agriculture.

There is continued difficulty in agricultural trade with the EU, and US corn exports to the EU remain essentially blocked, but soy exports—needed for animal feed—have generally continued. Equally worrisome are the active efforts on the part of the EU to

internationalize its approach to biotech regulation and to raise concerns among third countries that their use of GE crops could have deleterious consequences for their trade with the EU. Quite recently, the EU has proposed allowing individual member states to use non-science-based criteria to ban the use of GE crops determined to be safe by the EU's own safety authorities (EFSA). Such a step would appear to effectively fracture the essential common market idea of the European Union. Both US industry and government leaders have expressed grave concerns about this proposal.

With China difficulties persist also, after years of regular engagement at the technical, senior staff, and political levels, including even White House involvement. Although China is the largest importer of US plant-based agricultural commodities, the US continues to have trade issues with such exports to China. These issues derive from a systematic problem, namely, the Chinese requirement that products first be approved in their country of origin before safety reviews can even be started in China. This requirement guarantees asynchronous approval times in our two countries. Asynchrony then raises the likelihood that a product not yet approved in China could lawfully enter commerce in the US and wind up in exports to China, potentially leading to trade issues. I should note that US industry incorporates stewardship plans into product launches to prevent such situations from occurring, but reliable stewardship is contingent on an efficient, predictable, and transparent regulatory process in China—which is not what we in fact see.

In addition, in China new draft regulations for their GE crop approval process call for taking social and economic concerns (which may not have anything to do with science) into account in their decision making. These are also disturbing developments.

Late in 2015, President Obama raised the issue of regulatory problems with China's President Xi Jinping. One projected outcome from that meeting is an upcoming Strategic Agricultural Innovation Dialogue, which is to occur at the vice-ministerial level later this year. This is to be a high-level discussion on innovative technologies. The United States intends to have continued dialogue around agricultural biotechnology at this meeting.

Before I leave the topic of the status of biotechnology in other countries, it is worth noting briefly, as have other speakers today, that research on GE crop varieties as well as adoption of GE crops is moving forward around the world beyond the Americas, importantly in Asia and to a lesser extent in Africa. Field trials are taking place in a large number of countries.

USDA, the United States Agency for International Development, and the US Department of State are involved in capacity building and/or public diplomacy efforts that, broadly, (1) offer support for the development of science-based regulatory systems; (2) work with local stakeholders to identify local agricultural priority problems amenable to GE solutions; and (3) foster the development of public-private partnerships to leverage available useful technologies to address those problems. The United States government recognizes that increasing a country's familiarity with useful GE crops can help overcome hurdles retarding biotechnology adoption.

A few notable examples of recent developing country GE adopters are the Philippines and Vietnam, which have both allowed the planting of GE corn, and Bangladesh, which has recently commercialized *Bt* eggplant (*brinjal*). The United States provided technical support to these countries as they worked through the development of their own regulatory systems for GE crops and completed their safety assessments for these crops. Other capacity-building efforts by US agencies continue, such as ongoing efforts in Southeast Asia, particularly in Indonesia and Malaysia, and in Africa, with the South African Development Community (SADC) Member States (Angola, Botswana, Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia, and Zimbabwe), helping to facilitate field trials, and in the case of the SADC region, working toward regulatory harmonization.

To more clearly understand the complexities surrounding GE varieties in trade, it is important to consider how new GE events affect commodity trade.

The United States excels at production of agricultural commodities like corn, soybeans, and wheat. Commodity products—that is, non-identity-preserved bulk shipments—make up the bulk of US grain trade. Efficient commodity production depends on high-yielding and resilient varieties, commingling product from many sources, speed in handling, and efficiencies of scale.

US exports of two major crops, corn and soy, both mostly planted to GE varieties, exceeded $37 billion in 2014—a positive counterweight against our overall $505 billion trade deficit last year.

Worldwide commodity trade is constrained by asynchronies between potential exporting and importing nations in their approvals of new GE events.

The ability of exporters to keep GE events that are commercially grown, especially for commodity purposes, out of a particular export stream is limited. That means that traces of GE crops lawfully grown in one nation may show up in export streams going to importing nations where those GE events have not been approved. Such low-level presence (LLP) poses significant risk for trade disruptions.

Importing nations have a range of options:

1. Reject a shipment with LLP
2. Allow the shipment in and ignore the LLP
3. Conduct a risk assessment to guide future actions, which may or may not include full approval of the LLP product
4. Use some other basis to allow conditional imports of the shipment

The potential of shipment rejections poses significant economic risk for international grain trade. Shippers may incur substantial costs, including demurrage at initial destination ports and/or rerouting to alternate markets, and market uncertainties substantially increase the cost of doing business.

Additionally, the use of sensitive testing protocols for trace amounts of unapproved events imposes substantial costs on the industry and poses additional uncertainties due

to potential false positive results, sampling errors, technical difficulties, and the risk of different testing results being obtained at origin and at destination.

The US approach to addressing these issues focuses primarily on working with trading partners to minimize asynchronies in approvals. Efficient and predictable regulatory systems and simultaneous submissions in different market countries will eliminate most potential instances of LLP-related trade problems. That is the key first step.

Countries also need to be able to predict and address LLP incidents should they arise. The availability of information about a new material is key for regulators to be able to ensure the material's safety before addressing any legal issues it may pose. The United States actively encourages foreign developers to consult with our relevant regulatory agencies—the Food and Drug Administration and sometimes the Environmental Protection Agency—so that safety considerations can be examined early for materials that may show up in trace amounts.

So the overall picture is complex. Technology advances are necessary and are demanded by farmers. Innovation is essential to maintain US competitiveness. However, each new product potentially poses coexistence challenges and, in a marketplace where asynchronous approvals predominate, potentially poses trade problems as well: each new product may be a source of LLP. It is vital, therefore, that coexistence and trade challenges be addressed to maintain US competitiveness and to meet the global challenges of climate change and food security.

Speaker Profile: Michael Schechtman received a B.A. from Harvard University in biochemical sciences, a Ph.D. in molecular biology from Cornell University, did postdoctoral work in the Biology Department, Stanford University, and was formerly a member of the biology faculty at Syracuse University.

He serves as Biotechnology Coordinator for the Office of the Deputy Secretary of Agriculture. He was Executive Secretary of USDA's Advisory Committee on Agricultural Biotechnology. He was formerly Team Leader for Policy and Senior Microbiologist in the Regulatory Coordination and Technical Documentation Unit at the Animal and Plant Health Inspection Service at USDA, working on regulatory policy coordination and development regarding organisms produced through biotechnology. He was a member of the US delegation to the Biosafety Protocol negotiations under the Convention on Biological Diversity. He is also on the External Board of Directors of the US Agency for International Development Agricultural Biotechnology for Sustainable Productivity Project.

Enabling Coexistence: Balancing Innovation and Market Access

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As an agricultural and food company, Cargill is and remains a strong supporter of agricultural biotechnology. Cargill believes that this technology has an important role in nourishing the people of the world. But agricultural biotechnology's benefits are limited if these innovations cannot be effectively integrated into the global food system. International solutions are needed to deal with the current challenges of asynchronous approvals, where a technology is approved in an exporting country but not in an importing one. Compounding the asynchronous issue are policies in some countries with zero tolerance for the presence of any materials derived from biotechnology. The best solution lies with governments finding ways to synchronize approvals and moving the requirement for approved genetically modified traits off of zero tolerance.

Over the last ten years there have been significant changes in agricultural biotechnologies, in both business opportunities and risks. To understand the complexity of the marketplace, a broad overview on the US grain-handling system is in order. Firstly and most importantly, price and quality are the key drivers for both our domestic and international customers. The US bulk handling system is one of the most highly efficient grain-handling infrastructures in the world. Over the last 150 years, it has evolved to become world class in its ability to move large quantities of agricultural products from areas of surplus to areas of need. It generates tremendous value from farm to fork.

The result is a system based on grain standards that include reasonable tolerances and thresholds for commingling. This provides market access to fungible, high-quality agricultural products at low costs. It is this high-volume, efficient supply chain that has enabled it to be a fierce competitor in global agriculture and enabled the United States to remain a key agricultural supplier to the world. Sameness or interchangeability is a critical

component in commodity-handling systems and provides the flexibility to move grains and oilseeds efficiently. Over the last 100 years, essentially all countries have developed their bulk handling systems to take advantage of such fungibility.

Farmers have widely embraced growing a generic product, with clear specifications. This provides flexibility in where and when they can deliver their product and enables them to maximize profits through competitive price discovery. Specialty grains can deliver premiums to farmers but also trade off flexibility in where they can be raised and when they can be sold.

For those who originate and handle grain, fungibility has been a key attribute to enable efficient supply chains. Being able to substitute grain volumes ensures that there is a source of grains when there are crop failures or disease outbreaks in specific regions or countries. Swapping consignments of grain enables companies to arbitrage and find the lowest cost logistics when supply and demand ebb and flow, thus maximizing efficiencies and minimizing food miles.

Governments have developed grain standards and industry specifications to enable a commodity grain system to work. In response to governments and competitiveness on price, the private sector has responded with deliberate investments in large, high-throughput storage infrastructure and moving products with 100-car-unit trains, groups of barges, and large ocean-going vessels.

For both domestic and international customers, these generic grains have provided access to a safe, low-cost, and predictable food supply chain. For customers, it enables the bidding system for price discovery and access to the lowest-cost grains. It allows customers to source multiple origins and regions to ensure predictable supply and manage demand and price. It provides consistency in quality and safety, and predictability for running their manufacturing businesses.

But the bulk handling system, as it has evolved, is not designed for significant market segmentation or deconstruction into a series of parallel grain-channeling programs. This market segmentation quickly erodes price and competitiveness. It undermines fungibility and flexibility and all the benefits a commodity supply chain creates. It especially cannot operate effectively with zero-tolerance requirements.

For those involved in the agricultural industry, there should be little debate about the importance of exports to agricultural producers in helping maintain and grow demand for agricultural products. American Farm Bureau statistics tell an important story: one in three US farm acres is planted for export; 31 percent of US gross farm income comes directly from exports. There are large and important markets to serve, and exports are key to improving overall food security. Agricultural biotechnology's benefits to global food security are limited if they cannot be effectively integrated into the global food system.

Here is a simple illustration of the steps in a typical supply chain for a raw agricultural commodity:

- Crops are transported from farms to grain elevators. Grain elevators are most often designed for scale to help manage costs. For corn and soybeans, elevators

often have limited segregation capabilities, so they mainly accept generic commodities, such as yellow soybeans or number 2 yellow corn.

- A typical elevator accumulates grain from hundreds of different farms. Once elevated to the bin, the grain from a farm becomes part of a larger consignment, and there is no way to retrieve only that specific parcel again. Accepting something that is not allowed or has a negative attribute becomes very expensive very quickly, as it implicates larger consignments of grain.
- Bulk grain is further aggregated when sent for processing, either domestically or abroad. Most of the infrastructure is common regardless of whether the grain is processed domestically or transported to an export market.
- Once aggregated at export, a shipment of grain may contain product harvested from thousands of different farms. As such, the needs of the domestic and export markets must coexist.

Next, let us look at how GM crops have been integrated into agricultural supply chains over the last 15 years. The introduction of GM crops has added a new layer of complexity to the system. It has created a need for additional regulation, and today compliance requirements can differ by market. It has also created demand for non-GM products, which requires segregated supply chains for handling crops produced with and without biotechnology. Over this period of time we have learned a number of valuable lessons.

The integration of GM products into agricultural supply chains requires national frameworks to support the assessment and management of any risks associated with the use of biotechnologies. Product safety always comes first, and we believe governments can play an important role. While some see regulation as a barrier to innovation, national frameworks enable market participants to integrate new technologies into agri-food supply chains with confidence. Safety reviews by government authorities and independent scientific bodies provide assurances to industry and consumers. It is essential to know that a product is considered safe and is approved *before* it arrives at our facility.

We consider products to be safe if they have cleared governmental reviews consistent with Codex international risk assessment guidelines. Unfortunately, the existence of an international standard for safety assessment (Codex) has not prevented this problem. While national frameworks are essential, the lack of harmonization poses significant challenges. While current difficulties are not what was envisioned a decade ago, individual countries and more specifically key trading partners have not effectively coordinated regulatory approvals for new traits. National differences in both the timing and process for approving new traits can lead to regulatory compliance issues that must be managed. As such, agricultural commodities without key export market approvals are *not* fungible commodities and just because they are *safe*, does not mean they are *equal* and allowed to flow freely in international commerce.

Zero tolerance for unapproved traits has become a common regulatory requirement for commodities, yet totally unattainable after commercialization. As such, the commercial-

ization of new GM traits before export market approval is a *key issue* to be addressed by industry and governments based on the risks asynchrony creates for producers and the US agricultural industry. Without a solution, asynchronous approvals *can* severely hamper the movement of commodities from areas of surplus to areas of need. It undermines food security goals. At no time has this been more acute than the present.

An increasing focus on testing and enforcement adds pressure to asynchronous approvals. High-profile field escapes and awareness of asynchronous approvals reinforce government interest in testing and compliance activities. Driven by the need to assure regulatory compliance, GMO detection capabilities have advanced rapidly in recent years. Governments have invested heavily in efforts to improve methodologies, sensitivity, and speed. Testing technologies are now readily accessible and cost effective, and barriers to entry are low.

There are different views on this issue, depending on location in the value chain. From the technology perspective, there is a drive to commercialize, to start recouping the investment and to enjoy as much of a patent's life as possible. Technology companies spend significant amounts of money to both develop and obtain approvals for their traits. There is also a demand from farmers who want access to innovations that promise improved performance on their farms, to help them improve agronomics and yield.

It is a bit more complicated for the producer. The producer looks to maximize value creation on his farm, and this is a combination of yield and the market price for his grains. As such, producers are looking for both what can bring them the best yields and the marketability of those products. Individual grower decisions to produce GM products that lack export market approvals can both create marketability issues for that individual producer and, if not managed effectively by the technology company, dramatically increase cost and risk to the entire supply chain.

Most of the costs and risks that occur when unapproved traits are introduced into the supply chain are realized more broadly across the US producer base, grain handlers, and exporters. There are key examples that illustrate this to be the case. Ultimately, these additional costs and risks have the potential to reduce US competitiveness, by restricting access to markets where these products are not yet approved, by challenging the reliability of the origin as a key supplier, and by making US products less competitive on price.

Current market conditions, including the size of the export market, can change the calculus of this decision. The best outcome is for US agriculture to have both innovation and market access. As asynchronous approval barriers have emerged, industry approaches to address them have varied over time. Dialogue between the grain and export industry and government is essential and remains a key activity. It is clear, however, that there will be no quick fix to the patchwork of national approval systems. For integration of GM crops into global food systems, solving asynchronous approvals remains elusive.

Sensing long timelines, there is a growing impatience amongst some technology companies, who want to commercialize now. Over the last decade they have been exploring new ways to bring their products to market and are pushing the limits. The starting point a decade ago was "no commercialization ahead of key market approvals." This expectation was set

early by the soybean growers in the US, recognizing that they needed both innovation *and* market access. There is strength in being the preferred and predictable supplier to the world's markets. With a large export program it is easy to put the customer first. This has paid off for soy producers, who have been able to near double their export demand to over $20 billion over the last decade, while at the same time using agricultural biotechnology to improve both agronomics and sustainability.

For the corn industry, producers chose to rely much less heavily on exports, and different approaches to asynchronous approvals were used. One approach to asynchronous approvals was to broadly commercialize the GM event in the absence of the key market approval to apply political pressure in the destination market and force an approval before harvest. That happened in 2007. This broad commercialization decision drew significant attention from exporters in 2007, when the US corn market—the number one corn export market in the world—was put at risk. The industry hoped to never see that approach again.

One of the positive outcomes from this crisis in 2007 was the recognition and reinforcement across the value chain that US agricultural systems are interdependent. What followed were important cross-sectoral discussions around the need for a responsible commercialization model. This catalyzed the development of the Biotechnology Industry Organization (BIO) product launch stewardship policy and subsequently a similar global commitment through CropLife International (CLI). Both stewardship policies promoted "pre-commercialization" through tightly controlled closed-loop programs. In this case, technology owners hope to enable both innovation and market access by channeling the product away from the not-yet-approved markets.

Over time and based on the realities of the grain-handling system, it has been very difficult for biotechnology providers to demonstrate that they can completely segregate these products. There have been some valuable lessons over the last decade about the limits of closed-loop grain-channeling programs: if not managed effectively, they tend to leak. When they are poorly managed and leak, exporters have generally been expected to keep these unapproved events away from the export markets. Managing the presence of an export-unapproved GMO in the commodity supply can have a significant operational and financial impact on those outside of the closed-loop supply chain.

Some of the most important lessons have been:

- Outcomes are more important than process. Early attempts to channel corn away from the EU market demonstrated that it is not the plan on paper, but the execution of the plan that counts. Tying outcomes to responsibility is an important feedback loop.
- When containment systems fail, a little goes a long way. Based on the level of commingling that happens in the grain supply, a very small amount of production can have an impact on a very large amount of grain. With less than 1/10th of 1 percent of the corn supply planted to an unapproved trait, at one point 60% of the barges containing corn by-products feed, intended for EU customers, tested

positive and therefore, unacceptable for export. In the end, the prevalence and risk of the trait made it too expensive and risky to continue the trade flow, and that opportunity to export evaporated.

- Most importantly, zero is a very small number. For a zero-tolerance requirement, we have learned through experience that testing is not a robust risk management solution. Vessels may test negative at origin and test positive at destination; these have been powerful and expensive lessons.

With a recognition of the reality of agricultural systems and a zero-tolerance threshold, grain channeling is not a substitute for a key export market approval. Grain channeling has a role to play if executed with rigor, but this also adds cost and risk to the broader agriculture supply chain. These costs and risks need to be accounted for as part of closed-loop commercialization decisions. So given the realities of commodity supply chains, timing differences in government approvals, and varied commercial interests, where do we go from here?

There have been a number of conversations going on about how to sensibly address this issue in a manner that supports and encourages both innovation and market access. One of those has been a healthy discussion across the full value chain to look for consensus on what responsible commercialization standards would look like for the industry.

That discussion was built on recognition that commercialization ahead of key export market approval creates both costs and risks. Recognizing this alone has been important, so the discussion can begin about who should cover these additional costs and risks. Exporters and handlers will not accept all of the risk and costs that unapproved GM event commercialization brings to US agriculture. There is a growing recognition that when technology companies decide to commercialize early, grain handlers and exporters expect those who earn the value to also own the risk. At a minimum, the risk and reward should be shared.

The recent National Grain and Feed Association economic case study developed in April 2014 provides sense for such impacts. Based on conservative NGFA estimates, corn created approximately $80 million in economic value that accrued to the technology owner, seed sellers, and selected producers who grew it on 4 percent of US corn acres. But the resulting market disruption is estimated at $1.0–2.9 billion dollars in damages to all producers, handlers, and exporters. In this case study, it is clear that US agriculture lost significantly more than it gained from this aggressive commercialization decision.

The best solution lies with governments finding ways to synchronize approvals and moving the requirement for safety-approved GM traits off of zero tolerance. Governments should address these difficult challenges and find solutions quickly. This patchwork has turned out to be difficult to manage and is limiting biotechnology's integration into the global food system. Surely there are better ways to align and recognize the commonalities in approaches and assessments. It will take leadership and creativity to make significant gains.

Unresolved, asynchronous approvals slow innovation, erode the value of technology, and hinder the role of agricultural biotechnology in helping to address our food security

goals. In the near term there is an opportunity to address zero-tolerance policies for GM events that have been fully approved for food and feed use but not yet approved in a given importing country through the Global LLP Initiative. There is also some growing traction with governments to move off of zero tolerance. It is an opportunity to mutually recognize existing safety assessments, respect existing biosafety laws and, in a very practical way, address zero tolerance in the interim while full approval processes are completed.

There is a role for the US government to show leadership here by demonstrating a proactive and clear low-level-presence policy for the US. Many countries look to the US for guidance, and we need to walk the talk. Until these international challenges are resolved, the US value chain should be encouraged to continue to do the hard work in setting expectations around responsible commercialization. The stakes are high for everyone, and for real progress to emerge, technology companies will need to ensure they are standing together so that responsible commercialization standards are viewed as essentially mandatory. This will take strong commitment from them.

Over the 15 years since the commercialization of GM crops, we all have learned how interdependent agricultural supply chains are and that the best solutions will emerge when we are all pulling in the same direction. Even with the best efforts of industry, we will not resolve the issue of asynchronous approvals alone. Some of the key policy decisions for addressing asynchronous approvals fall to government, and those national government policy decisions have the potential to either improve or disrupt the implementation of agricultural biotechnology. There is no question that the quality of their policy decisions influences price, supply chain access, and food security impacts. The full value of the technology can be recognized with all stakeholders working together.

Speaker Profile: Randal Giroux is vice president at Cargill Inc. He leads Cargill businesses in the areas of food safety, quality, and regulatory, and has overall global responsibility in these areas for Cargill's agricultural supply-chain businesses, Cargill's grain and oilseeds businesses, world trading, sugar, and palm.

Worlds Apart on GMOs—Can Trade Agreements Bridge the Gap?

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Introduction

> *Our standards on consumer protection, on the environment, on data protection and on food are not up for negotiation. There is no "give and take" on standards in TTIP.* –EU Trade Commissioner Karel De Gucht[1]

The World Trade Organization (WTO) rules applicable to agricultural biotechnology predate the commercialization of genetically modified (GM) crops; the negotiating agenda for those rules was established in 1986 in the lead-up to the negotiations called the Uruguay Round. The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) is the applicable area of WTO law and dates from 1995. All members of the WTO accepted the SPS, including the European Union (EU). In the wake of commercialization, agricultural biotechnology became a contentious political issue in some countries, and the science-based SPS rules became politically unacceptable in some jurisdictions. As a result, domestic regulatory regimes and trade rules surrounding genetically modified organisms (GMOs) developed in an unharmonized fashion across the world, inhibiting international trade (Hobbs, 2007; Isaac, 2007). Nondevelopment of a global market for GMOs has led to reduced markets for those investing in the development and commercialization of new GM products and, hence, reduced expenditures on research. Multilateral trade negotiations have made no progress since 1994, and some countries wishing to break the impasse have been looking to preferential trade agreements for solutions. This paper examines the problems in the multilateral system pertaining to

[1] European Commission (2014).

trade in GMOs and assesses the likelihood that preferential trade agreements such as the Transatlantic Trade and Investment Partnership (T-TIP) or the Trans-Pacific Partnership can provide a way forward.

One of the reasons that agricultural biotechnology became such a contentious public policy question is that it is an issue where four already existing groups with strong preferences coalesced (Kerr, 2001). In this, agricultural biotechnology is unique. These civil society groups were (1) people who were already concerned about the quality of the food they were eating,[2] (2) people who were interested in protecting the natural environment, (3) people who questioned the ethics surrounding the technology,[3] (4) people disturbed by the influence of large multinational firms on the food industry.[4] Given the strength of the preferences held by these individuals, and the civil society groups they formed (or joined), biotechnology became a lightning rod for protest and political activity. In the EU it became an issue akin to gun control in the US. Over time, anti-GM vested interests arose in, for example, the organic industry[5] and some NGOs, which found "beating the anti-GMO drum" a good fundraising strategy (Marantelli, 2002).[6] The resulting divergence in domestic regulatory policies toward GM products has led to a gradual increase in trade barriers to GMOs around the world. These trade barriers have economic effects that far exceed the disruptions to trade flows because they inhibit investment in research and development in GM crops (Smyth et al., 2011).

Evolving International Trade Regimes for Agricultural Biotechnology

The WTO

In the approximately 20 years since the SPS came into force in1995 with the conclusion of the Uruguay Round, and coincidently the first commercial planting of GM crops, there has been no change to the WTO's rules governing trade in GM products, although there has been considerable clarification of those rules through adjudication of disputes. The major reason that no changes have occurred is that opening of the SPS for renegotiation was not included in the agenda of the Doha Round that commenced in 2001. Of course, the Doha Round was never expected to take the time it has and is currently languishing in a diplomatic limbo with no end in sight. Any changes to the current SPS will require an end to the Doha Round, followed by an agreement to have a new round along with opening the SPS for renegotiation. Given the vested interests of

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[2] Manifest in preferences for organic food, vegetarian diets, health foods, etc.

[3] Concerned, for example, about transgenic transfers of genetic material that could not happen with natural selection—in essence concerned that developers of the technology are "messing with God's work."

[4] Given that most biotechnology crops were being developed by large agribusiness firms that possessed intellectual property rights in their innovations.

[5] The organic industry self-proclaimed itself GMO-free, astutely surmising that it could attract additional customers among those who did not wish to consume GM foods. Coexistence policies were then requested to protect this vested interest.

[6] Examples of such fundraising efforts by NGOs can be found at http://www.cban.ca/donate and http://watchdog.org/168910/vermont-gmo-food-fight-fund/.

some countries such as the US and Canada in the current science-based SPS rules, there is little likelihood of a major initiative to alter the SPS within the WTO's consensus-based decision-making framework.

Having agreed to having science as the basis for decision making in trade rules pertaining to sanitary and phytosanitary issues, some countries have found it very difficult to live up to their SPS commitments when putting in place their domestic policies—and biotechnology is at the heart of those difficulties.[7] Groups in civil society have lobbied their governments strongly for both domestic production bans and import restrictions. Their basic position is that they do not want the technology used in their environment and do not want products derived from the use of the technology in their markets. The WTO has no mechanism to allow governments to respond to such demands from groups in civil society and, hence, governments under such pressure have had to seek alternative justifications for restricting market access (Kerr, 2010).[8] Governments facing strong pressure turned to the SPS to justify trade restrictions. When they did they ran into the need for a scientific justification. The underlying premise of the SPS is that members of civil society will defer to scientific experts (Smyth et al., 2011). This has proved to be a flawed assumption in the case of those with strong anti-GM preferences. They argue that there is no consensus among scientific experts,[9] that insufficient science has been done, and that scientific experts are in the pay of multinational companies. WTO panels have tended to defer to scientific experts when judging SPS issues, leading to SPS-based barriers being struck down.[10]

Until 1999, EU GM policy was roughly in line with science-based regulation. In 1999, in reaction to rising concerns expressed in civil society, the existing policy was withdrawn, and a new regulatory and trade regime was to be developed. In the interim, until a new policy could be developed, a moratorium on approvals of GM crops and imports was put in place. The development of a new EU regulatory regime, however, proved to be very difficult and time consuming. Faced with the ban, the US, Canada, and others brought

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[7] Of course, biotechnology has not been the sole domestic regulatory issue where conformity to SPS rules has been a challenge. The first major test of the science-based principle of the SPS was the EU ban on imports of beef produced using growth hormones. It led to a failure of the EU to comply with a ruling from a WTO panel and subsequent retaliation by the US and Canada (Kerr & Hobbs, 2005). Accepting retaliation, while part of WTO law, has seldom occurred, and the EU's use of this escape from its commitments is unprecedented (Kerr, 2006a).

[8] The entire intellectual foundation of the 1947 General Agreement on Tariffs and Trade (GATT) is a partial equilibrium neoclassical trade model in which consumers are expected to benefit from the lowering of trade barriers–and thus never ask for protection. Only producers benefit from trade barriers and are expected to ask for or fight to retain barriers. Thus, the GATT/WTO rules did not anticipate calls for protectionism from consumers (and other groups in civil society) (Kerr, 2007).

[9] Though the SPS looks to a scientific consensus for decision making, the reality is that while an overwhelming majority of scientists may agree on a particular paradigm, there is never a full consensus among the scientific community. Scientific progress is premised on the idea that there will always be those who challenge the ruling orthodoxy. Thus, those looking for scientists who have dffering views on, for example, climate change or biotechnology, are likely to find them (Symth et al., 2011).

[10] In the case involving the EU ban on beef produced using growth hormones, the EU's own scientific experts found no scientific reason to support the ban (Kerr & Hobbs, 2005).

a case at the WTO. The essentials of the new EU regulatory regime for biotechnology were put in place in 2003 but remain a work in progress. The WTO panel brought down its judgment in 2006 and found the EU in violation of its WTO commitments (Viju et al., 2012). In response, the EU stated that its new policy would comply with its WTO commitments but that it would take time to come into compliance (Viju et al., 2012). The new EU regulatory regime allowed for approvals of GMO cultivation and imports, but approval is a slow process. Thus, it took a considerable period to discern if the regime was compliant with the science-based principles of the SPS. It does not appear to be in compliance, primarily because science only informs the approval process, and a political process that can consider nonscientific factors in its decisions ultimately decides on GM approvals and trade measures (Viju et al., 2012). The EU's regulatory regime, however, would require a new challenge through the WTO dispute settlement system to definitively determine if it is compliant.[11] As yet, no such challenge has been mounted. This is the current situation with regard to biotechnology at the WTO. There is little or no prospect of renegotiating the SPS, and any change in the status quo will have to await a challenge through the dispute system.

Events in the EU, however, may precipitate new challenges to the EU regulatory regime. Disruption to trade flows arising from detection of a low-level—or adventitious—presence of GM material in shipments of non-GM crops is likely to become a growing problem as more and more GM crops are approved around the world. The EU has a zero-tolerance policy toward such commingling, meaning the refusal of shipments and ongoing import embargoes in the wake of the detection of low-level commingling (Hobbs et al., 2013). A reasonable case can be made that this facet of the EU import regime is not compliant with the SPS because the import refusals and embargoes do not conform to the requirement to examine scientific evidence and to carry out a risk assessment (Viju et al., 2014). Of course, a determination of the compliance of the EU regulatory regime pertaining to low-level presence will have to await a WTO challenge.

The second major potential area in which a challenge might be mounted is in response to the current changes in the EU governance of GM approvals. It also points out how visceral an issue GM technology has become within the EU. While the current EU regime for approvals of new GM crops may not be WTO compliant, it has approved new varieties recently.[12] The approvals mean that the GM varieties can be grown EU-wide.[13] This has proved to be very contentious in some EU countries, and a process for individual countries to opt out of growing approved GM varieties is working its way through the EU political institutions. In the trade context, the EU negotiates as a single entity at the WTO and, hence, its policies must apply across all states. If seed imports are, for example, allowed by some EU member states but not others, this could be cause for a challenge.

[11] It should be remembered that a country can use any trade measures it wishes in the absence of a challenge through the dispute system.

[12] The process is slow, costly, and risky. Approvals have taken up to five years (Viju et al., 2012).

[13] Subject to the coexistence regulations of individual member states.

The Biosafety Protocol

While the EU and other countries facing strong anti-GM pressure have chafed under their commitments to the SPS and been frustrated by not being able to renegotiate its provisions, they have not sat idly by. They observe that a number of multilateral environmental agreements (MEAs) have trade provisions that differ from those of the WTO (Kerr & Hall, 2004).[14] The MEA that has been negotiated to deal specifically with trade in GMOs is the Biosafety Protocol (BSP) within the Convention on Biological Diversity (CBD). The EU has been a major proponent of the BSP, and a large number of countries have ratified it. While the initial rationale for the BSP was to protect biological diversity, early on its remit was extended to deal with threats to human health (Holtby et al., 2007). The major differences between the BSP and the SPS are that the BSP (1) requires that science only need inform decisions to put trade barriers in place against GMOs and need not be the only consideration in decisions, (2) formally recognizes the precautionary principle, and (3) has no dispute settlement mechanism (Hobbs et al., 2005). The latter means that an importing country can unilaterally undertake a scientific assessment leading to trade barriers, can allow nonscientific factors to trigger the imposition of trade barriers, and can invoke the precautionary principle as a justification for import barriers without any recourse for exporters. There is no mechanism for an exporter to challenge the basis of a decision by an importer. There is no mechanism to challenge the use of other considerations when imposing trade barriers under the BSP.[15] There is no mechanism to challenge the "absence of sufficient scientific evidence" used to justify an importer's invocation of the precautionary principle. In essence, it gives importing countries a virtual carte blanche to impose trade barriers (Hobbs et al., 2005; Holtby et al., 2007). Thus, it removes the major constraints imposed by commitments in the SPS.

The BSP, however, does not allow the EU and other subscribing countries to fully escape the SPS. This is because the US, Canada, and Argentina—major producers and exporters of GMOs—have not agreed to sign the BSP.[16] Under international law, the provisions of the BSP cannot be applied to them and, rather, as almost all countries belong to the WTO, it will handle disputes under the provisions of the SPS agreement. If, however, both countries in a dispute have acceded to the BSP, then, under international law, the "later in time" BSP would apply (Kerr et al., 2014b).[17] The EU has actually been "encouraging" countries to sign up to the BSP by, for example, making the granting of reduced tariffs to developing countries under the general system of preferences (GSP) contingent upon the recipient countries' acceding to the BSP (Khorana et al., 2012). Similar requirements to

[14] Well-known examples include the Convention on International Trade in Endangered Species and the Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.

[15] One of the main reasons for negotiating the SPS was to prevent the imposition of nefarious trade barriers justified on SPS grounds whose actual goal was to provide economic protection (Smyth et al., 2011).

[16] As the US has not ratified the CBD, it is not eligible to belong to the BSP (Holtby et al., 2007).

[17] There are issues with the later in time principle in international law. For example, if the Doha Round were to be successfully completed in the future, it is not clear whether the resulting WTO rules would then be considered later in time than the BSP (Kerr et al., 2014).

accede to the BSP are embedded in the regulations surrounding whether a country can supply biofuels to the EU market and receive credit toward meeting the quantity mandate for renewable fuels (Williams & Kerr, in press).

Preferential Trade Agreements

Given the stalemate in the Doha Round, countries have been turning to preferential trade agreements to achieve progress in trade liberalization. Three will be dealt with here: the Comprehensive Economic and Trade Agreement (CETA) between the EU and Canada, completed September 2014; T-TIP; and TPP. These agreements may provide a number of insights regarding the influence of trade agreements on policy making for GMOs.

The EU and Canada negotiated for almost six years before CETA was agreed. Canada is one of the major adopters and developers of biotechnology and has, some would argue, suffered disproportionally from EU policy on GMOs: Canadian canola's being shut out of the EU market for oilseed rape; the Canadian flax market's suffering trade disruptions, loss of market, and high testing costs due to an adventitious presence incident (Viju et al., 2014); and, arguably, the failure to commercialize GM wheat. Canada definitely had an interest in gaining some concessions from the EU regarding market access for GM products. Despite assurances from Canadian negotiators that "everything was on the table," there was speculation that the EU would prove to be intransigent on the issue (Viju et al., 2010). The negotiations were held in strict secrecy, so positions remained unclear, but there were indications that the negotiations in this area were difficult (Viju & Kerr, 2011). The secret negotiations also allowed for a diplomat's solution to the problem—an agreement that allows difficult issues to be "kicked down the road." What was agreed was the establishment of a mechanism for dialogue on issues related to biotechnology—a place to talk and talk but with no mechanism to bring closure to the issues discussed. The CETA text on biotechnology reads as follows:

Article X.03: Bilateral Cooperation on Biotechnology

1. The Parties agree that cooperation and information exchange on issues related to biotechnology products are of mutual interest. Such cooperation and exchange of information will take place in the bilateral Dialogue on Biotech Market Access Issues …. The dialogue covers any relevant issues of mutual interest to Canada and the EU, including, among others:

(a) Biotechnology product approvals in the territory of Canada or the EU as well as, where appropriate, forthcoming applications of commercial interest to either side;

(b) the commercial and economic outlook for future approvals of biotechnology products;

(c) any trade impact related to asynchronous approvals of biotechnology products or the accidental release of unauthorised products, and any appropriate measures in this respect;

(d) any biotech-related measures that may affect trade between Canada and the EU, including measures of EU Member States;

(e) any new legislation in the field of biotechnology; and

(f) best practices in the implementation of legislation on biotechnology.

Listed topics are largely those of interest to Canada and likely represent the only concessions Canada could obtain in the negotiations. This was a clear win for the EU.

In addition to the official text of the CETA, there was a side letter from Tonio Borg of the EU Commission addressed to the Canadian Minister of Agriculture, Gerry Ritz, dated April 24, 2014, which states:

> The Commission will ensure that proposals for the authorization of genetically modified (GM) events, in particular GM canola, are processed as fast as possible within the procedures laid down in the EU approval legislation, e.g. submission of decisions to the Member States once an EFSA opinion is available. (Ref Ares, 2014)

It is not clear exactly what advantage this commitment would give Canada. GM events will still have to clear the scientific assessment of the European Food Safety Authority (EFSA). Further, EU post-EFSA procedures, which are cumbersome and time consuming, will still have to be followed.[18] Of course, there is no guarantee that a Canadian GM event would be approved once submitted. Further, given current moves to allow individual member states to deny approval for GM events even after they receive EU-wide approval may erode even the limited benefits that may arise from the letter.

The T-TIP negotiations represent an attempt by the two largest developed economies to garner some of gains from trade liberalization that have not been forthcoming from the Doha Round. The negotiations are being conducted in strict secrecy, so it is hard to know the direction bargaining is taking. For GMOs the official position of the US is that science (often referred to as "sound science") should form the basis of trade rules for GMOs—i.e., the rules of the SPS. Further, incidents of adventitious presence should be dealt with in ways that commercial shippers can reasonably accommodate—i.e., the EU zero-tolerance rule should be relaxed. The US also wants the time for EU approvals to be reduced. The EU, on the other hand, wants its current system, whereby science informs decisions, but the ultimate decision lies in the political sphere. In other words, there is a double hurdle: first pass the scientific test, then the political test. It will not contemplate lowering its human health and environmental protection standards. Further, it is currently a difficult time for the EU to negotiate over GMOs because its domestic regulatory regime is in considerable flux, with member states insisting that they not be bound by EU-wide decisions to approve new products. For the EU Commission negotiators, any concessions will be difficult. Thus far, outside the (secret) negotiating room, few suggestions for compromise are being floated.

There has been considerable discussion of harmonization, but largely in the realm of general principles rather than specific—or realistic—proposals. Harmonization can mean a number of things. Suppose two countries, A and B, have differing standards and regulatory procedures. Changing standards will impose costs. There are three possible outcomes: (1) country B harmonizes to the standards of country A, meaning B incurs all the costs of

[18] See Viju et al. (2012) for a description of the EU's procedures for approving GMO events.

harmonization, (2) country A harmonizes to the standards of country B, and A incurs all the costs of harmonization, and (3) the two countries collaborate to develop a new joint set of standards, with both bearing some of the costs associated with change. Of course, A prefers the first outcome, and B the second. Either of these outcomes can arise from trade negotiations. Thus far, in the US harmonization discussions seem to revolve around the EU harmonizing to US standards, no matter how unrealistic that outcome is. In the EU there is little direct discussion of the US harmonizing to EU standards—although the hard line taken on the sanctity of EU food safety and environmental standards suggests that this is the only logical harmonization outcome.

If none of those harmonization options are likely outcomes, then new joint standards must be developed. This cannot be done in a trade agreement. These will be long and difficult negotiations. All that can be agreed in something like the T-TIP is that these discussions will take place. This is the CETA outcome. The trick is to embed something in the agreement that will force closure on the negotiations. This was not the case in the CETA so, while discussions are mandated, they can go on and on without end. The NAFTA experience is relevant. A large number of institutional arrangements were built into the NAFTA to foster regulatory harmonization (Kerr, 1992). In general, they have not worked as expected (Kerr, 2006b). This is largely because they were constituted with no closure mechanisms and became no more than discussion forums (Kerr, 1997).[19] If there is to be harmonization regarding biotechnology in the T-TIP, it will require institutional innovation to force closure on the process of devising a mutually acceptable system.

The Trans-Pacific Partnership negotiations represent an ambitious attempt to move the trade liberalization agenda forward in response to the Doha Round stalemate. It is notable in that it involves 12 countries; both the US and Japan are part of the negotiations; it involves a mix of developed and developing countries; and it is open to additional countries joining even after negotiations have begun. Each of these features alone complicates negotiations; together they present a significant challenge, and it will represent a major diplomatic achievement if the negotiators can come up with an agreement (Kerr, 2013). The 12 countries involved are Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, the United States, and Vietnam. While the challenges are great, most of the countries involved are kept together by the singular motive of garnering better access to the US market.[20] For the US, better access to the Japanese market is a priority, but having a major trade-liberalizing agreement success is also important.

The regulatory and trade regimes for agricultural biotechnology show little commonality across the 12 countries. Table 1 summarizes the major policy measures of the countries

[19] There was one attempt to put a mechanism for closure into the 1988 Canada-US Trade Agreement (CUSTA) that preceded the NAFTA. This clause dealt with antidumping and countervail actions and provided for a seven-year negotiation process to devise a new, mutually acceptable, dispute settlement system for such actions (Kerr, 1988). If there was no successful resolution to the negotiations, the entire CUSTA could be cancelled. There was little progress, and the deadline was quietly removed in the subsequent NAFTA negotiations in 1994 (Kerr, 2001b). No harmonized system for disputes relating to dumping and trade-distorting subsidies between the US and Canada yet exists.

currently negotiating the TPP. All of the countries are members of the WTO and, hence, the SPS. Six countries, however, have ratified the BSP, suggesting that they may be seeking an alternative to the SPS for trade GMOs. In the case of the developing country members of the TPP, for the most part, their regulatory regimes are in various stages of development. Four countries have moratoriums on cultivation of GMOs. Two countries have import bans, at least until regulations are developed. For Peru the import ban will remain in place until 2022, at the very least. Japan, Australia, and New Zealand require labeling of GM products, and some other countries are developing labeling regulations. Chile allows the cultivation of GM crops for seed purposes but does not allow domestic commercial cultivation. In short, countries taking part the TPP negotiations appear to be far apart in their approaches to the regulation of agricultural biotechnology.

Harmonization is a goal of the US. Is what is being envisioned harmonization to the US standards and processes? Given how contentious the issue of GMOs is in, for example, Japan, New Zealand, and Peru, this outcome seems unlikely. This means harmonization will require devising a new, mutually acceptable, regulatory framework for biotechnology. As suggested above in the context of the T-TIP, this cannot be done through a trade agreement. What likely can be achieved in the agreement is the institutionalization of future discussions regarding biotechnology. The efficacy of that process then depends on whether some form of closure to those discussions can be put in place—otherwise they will be places to talk and talk.

Conclusions

To gain enthusiasm and support for a potential trade agreement, a great deal is typically promised. While trade theory suggests trade liberalization is welfare enhancing, trade liberalization also produces both winners and losers. Potential losers can be expected to pursue a protectionist agenda. In the wake of the success of the GATT in reducing tariffs and other formal trade barriers over 50-plus years, trade barriers are increasingly found in domestic regulations. To achieve further liberalization means that agreements must reach deeply into domestic regulatory competencies. The international governance of GMOs represents that form of liberalization challenge. Given the strong desire of US biotechnology companies to gain improved access for their products across the world, and the equally strong anti-GM preferences of some segments of civil society (and some governments), where trade and regulatory restrictions on GMOs are onerous, there appears to be little room for compromise. Effective negotiations require room to compromise. Preferential trade agreements are currently the "only game in town" in terms of trade liberalization. In the past the US and EU may have been able to use their economic muscle to obtain

[20] The two exceptions may be Canada and Mexico, which already have preferred access to the US market under NAFTA. They certainly could be motivated by not wishing to see their preferred access eroded. Mexico is particularly sensitive to increased competition in the US market from other developing countries, and Canada has an incentive to maintain its preferred access for products such as beef, which international competitors such as Australia and New Zealand do not have. Of course, they are interested in garnering better access to the Japanese market and opening up new developing country markets.

TABLE 1: Regulation of GMOs in TPP Countries

	SPS	BSP	Cultivation Ban	Import Ban	Labeling	Other
Australia	Yes	No	Not nationally but depends on individual states	No	Yes	
Brunei	Yes	No	Yes *(no regulations yet developed)*	Yes *(no regulations yet developed)*	Not applicable	Regulations being developed
Canada	Yes	No	No	No	No	
Chile	Yes	No	Yes	No	No	Regulations being developed GM seed produced for export only
Japan	Yes	Yes	No	No	Yes	
Malaysia	Yes	Yes	No	No	Under development	Regulations being developed
Mexico	Yes	Yes	No	No	No	
New Zealand	Yes	Yes	Yes	No	Yes	
Peru	Yes	Yes	Yes *(until 2022)*	Yes *(until 2022)*	Not applicable	
Singapore	Yes	No	Not applicable	No *(no regulations yet developed)*	No *(no regulations yet developed)*	Regulations being developed
United States	Yes	No	No	No	No	
Vietnam	Yes	Yes	No	No	Under development	Regulations being developed

better terms in their regional trade agreements (Kerr & Hobbs, 2006; Kerr, 2006c). In the case of the T-TIP, they face each other, and no significant economic advantage exits. In the TPP, Japan acts as a considerable counterbalance to the United States.

It seems that neither the T-TIP nor the TPP can deal directly with the majority of issues surrounding trade in the products of biotechnology. The answer lies in harmonization, but devising a new set of rules for trade in GMOs is beyond the scope of trade negotiations and will require separate long and complex negotiations. Trade agreements can, however, mandate future negotiations on devising new, mutually acceptable, rules of trade for GMOs. The trick will be to find an institutional mechanism to carry such negotiations through to a successful conclusion.

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Trade and Markets

Q&A

MODERATOR: DAVE ABLER

R. Welch, Syracuse University: I will be speaking later and I was worried you were going to steal my thunder. You did steal some of it, but hopefully I can add something. I used to work for the Foreign Agriculture Service in 1989–91, and we were definitely talking about STS and biotech. It was coming down the pike, and the general consensus was STS was going to be a very useful tool against you. Everybody thought so. It was definitely on the radar and my question is if regulatory regimes aren't more than just trade barriers? Aren't they also ways for people who want to organize their societies and address their problems? So is it impossible to harmonize regulatory regimes across different cultures and societies?

Kerr: I think it is probably difficult, but I agree with you. I think we have to explore this because I do think over the long run the cost of not having some kind of organization is very high.

Schechtman: I will add two quick things: one is that the goal of harmonization with the EU is something that maybe we were doing less specifically bilaterally on biotech, certainly back in the years you were talking about. We were also not working with the expectation that we could harmonize with the EU on this subject. The other is that maybe a center for cooperation meant to reach these agreements is not the only venue, there is also this whole idea that two countries can agree to the same level of protection. Though we have a lot of trouble with the EU on biotech issues, we were able to reach an organic equivalency, which doesn't mean that we necessarily follow exactly the same route, but that we are reaching the same place.

R. Roush, Penn State: The overarching impression I have of the whole panel is that while we may break out of this log jam, at least some of us in the audience are aware that various anti-GM activists are traveling through the developing world offering biosafety training

sessions which are a thinly veiled opportunity for them to make GM crops sound as dangerous as possible. Hundreds of studies have been done in the United States on impacts, and repeated in those countries to make sure there couldn't be any possible differences. This is happening all the time in an effort to stir the pot. I came away from listening to all three talks asking, what do we really need to do to get international approval? I can appreciate what you offer. It is difficult, but something has to be done outside the box to try to break this log jam. I am wondering if there are any ideas about this out there.

Giroux: I think more than in the industrial world, in developing countries consumers hear positive messages about biotechnology, so it is easier for folks to embrace that technology. The negative comments on biotechnology are all flowing in the same direction, they use those negative comments to influence the discussion. Maybe they haven't really figured it all out. If 1 in 1,000 safety studies says it may not be safe, we in this room as scientists recognize that that means nothing, right? The weight of evidence of the other 999 studies has not been disproved by a single study. The average consumer doesn't understand that. They don't understand the scientific process. So how do we make sure that the overwhelming messages going to consumers and national governments are positive messages about biotechnology? We need to find ways to minimize negative messages or the perception that there is a lot of infighting going on.

R. Roush: To follow that logic would be a bit like going on the *Daily Show*, so when they say that we need to show scientific balance on climate change, we follow two climate change skeptics with 98 climate change supporters. You are suggesting that ultimately it is still a media battle.

Kerr: Just to follow that up, agriculture and many consumers are actually very willing to accept the science.

T. Shelton, Cornell University: I have a specific question for Randall. You mentioned biotech traits in the United States in soybeans would cut off trade options elsewhere. You are probably aware that Brazil right now is contemplating the release of soybeans that have insect resistance, particularly to the soybean looper. Now a lot of people at the entomological meeting think this is a very dubious undertaking. There is a question about whether Brazilians will be able to manage the resistance potential well by establishing refuges and whether the trait is even actually needed to increase production of soybeans in Brazil. If they do succeed in adopting this in Brazil, would it mean they will be faced with a nontariff trade barrier in Europe the United States won't have, or will that be the loss of the European market?

R. Giroux: First of all it is interesting that a number of our trade partners or trade competitors also require a market impact assessment ahead of that commercialization as part of their biotech approval process. I can't give you any response, I'm just not an expert in that area. What I do know is that the Brazilian government and Brazilian agriculture are very keen on market access. They are very clear that market access is their number one priority. Building Brazilian agriculture, building infrastructure, finding export markets

for what is one of their key industries, and so we should anticipate the decisions to make sure that those markets remain open for Brazilian farmers.

T. Shelton: We have been talking about what the US is doing to try to prevent these damaging situations to US agriculture. You mentioned other countries like Brazil or Chile: Are they handling things any differently? Maybe you touched on it by saying they look for more premarket approval, but is there a working group with the US and Brazil and Argentina and the other GM-producing countries that can work together to try and solve this dilemma, or are we just going to have a lot of individual preferential trade agreements?

Giroux: There are two that I am aware of. There is the International Soy Growers Alliance, which represents 95% of the exportable soybeans of the world. Members are the US, Canada, Brazil, Argentina, and Uruguay. And they have declared that there be no commercialization ahead of key markets. So they are very much aware that in the Western Hemisphere market access for soybeans is critical. They don't accept grain channeling as a solution. I understand that therefore they will not commercialize ahead of key markets. What is the key market for soybeans? China. So, regardless of how difficult China is as a customer, they are THE most important customer for soybeans in the world, and you should take advantage of that. There is also a group of maize organizations called Maizol which is a collection of corn grower associations, and they struggle with the same issue. How do we enable market access for US corn? So there are organizations that are looking specifically at this issue of market access. So do we just try to outnumber the EU after a while? Vietnam is now producing corn. Indonesia and Malaysia were mentioned. Basically just try to get a lot of other countries producing it and then outnumber the EU?

T. Shelton: So do we just try to outnumber the EU after a while? Vietman is now producing corn. Indonesia and Malaysia were mentioned. Should we basically just try to get a lot of other countries to produce so as to outnumber the EU?

Giroux: I don't think about it that way. I think we just have a collection of customers who have specific attributes that they want and we are going to serve those customers. And so customers we can serve will become preferential destinations for products. If we have predictability, reasonable regulatory expectations, and can move those grains and oil seeds, those countries will be preferred over others that are more difficult. And generally if they are difficult you are going to have to pay more for what you want.

SESSION IV: SOCIAL AND ECONOMIC DIMENSIONS OF SUSTAINABILITY

The Structure of US Agricultural and Food Research, with an Emphasis on Seed-Biotechnology Research

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The complex US system of research for agriculture and food is composed of a variety of funders—USDA, other federal entities, states, and the private sector. Three major classes of research performers include two from the public sector: USDA intramural research, and research done at the State Agricultural Experiment Stations and other institutions. In recent years, research investment by the third performer, the private sector, has grown more rapidly than public sector research investment, which it now surpasses by a considerable amount.

Public sector research investments are spread across a broader array of research topics, including socially important areas such as the environment and food safety, but private sector research dominates farm machinery and food manufacturing research. Much of the private sector research in food manufacturing consists of new product development. The public sector invests more in animal research—much of the private sector research in this area is in animal health product development, as Figure 1 shows.

Complementarity of Public and Private Research

Crop research shows significant R&D investment by both the public and private sectors. A recent influential report by the President's Council of Advisors on Science and Technology (PCAST, 2012) suggested that the public sector should consider potential "overlap" with private sector research when determining allocation of research resources. Differences in the nature of the research conducted, however, suggest complementarity of public and private research. Frey (1996) conducted a near-census of plant breeders in both public and

* The views expressed are those of the author and should not be attributed to the Economic Research Service or USDA.

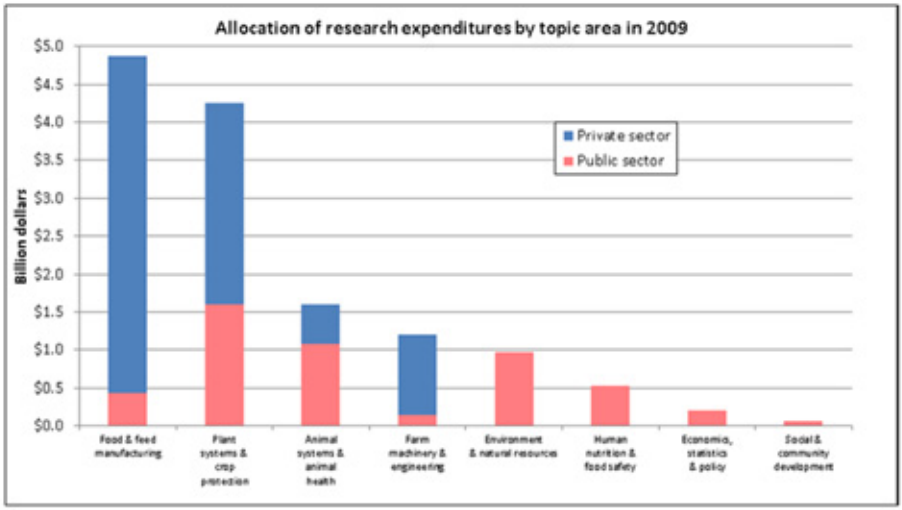

Figure 1. Public agricultural research investments:
Public and private sectors invest significant amounts in crop-related research.
Source: USDA Economic Research Service, based on Current Research Information System and Fuglie et al. (2011).

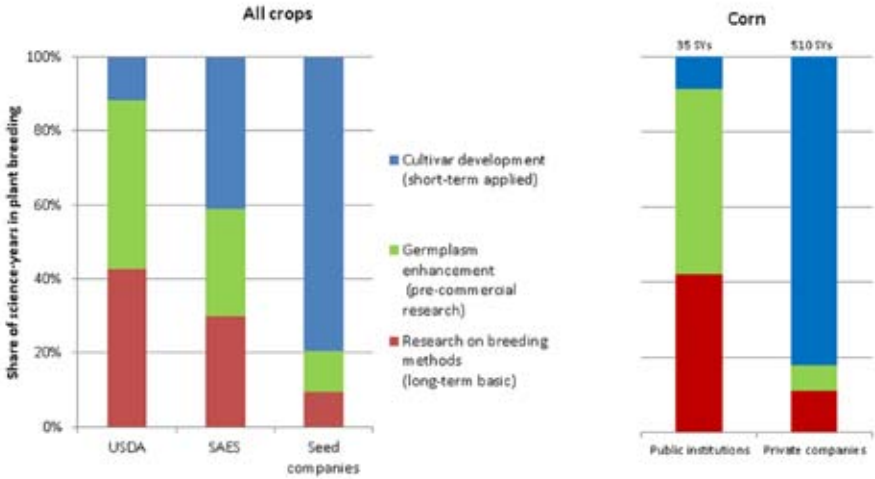

Figure 2. Differences in public and private sector plant-breeding activity allocation (National Plant Breeding Study, 1994).
Source: Calculated from Frey (1996).

private sectors in 1994. He found that of nearly 1,500 breeders in the private sector, 80% were concentrated on downstream "cultivar development." The more upstream categories of "germplasm enhancement" and "basic plant breeding research" were primarily in the public sector, where two-thirds of the roughly 700 scientist-years were occupied in these activities. This breakdown could also be observed for a major crop like corn, where over 80% of the roughly 510 private sector scientist-years in corn research were occupied with cultivar development, while less than 10% of the only 35 public sector scientist-years in corn went to cultivar development. Figure 2 shows this relationship.

Fuglie and Walker (2001) used the Frey data and controlled for market size and other factors. They found that higher levels of public upstream research were associated with higher levels of private cultivar development. Only higher levels of public cultivar development suggested the potential for public research to "crowd out" private cultivar development. The early history of corn research in the US, the resource allocation in Frey's data, and more recent history all show the public sector has, indeed, rebalanced its corn research portfolio in response to increases in private investment.

Comparable data are not available for a more recent period, but the evidence for all public and all private research suggests, in general, complementarity (Fuglie & Toole, 2014). Wang et al. (2013) found evidence of complementarity for public and private crop research (i.e., all crop research, not simply seed-biotechnology research).

Another facet of the perception of the dominance of private seed-biotechnology research is the fact that this category has been the major growth area among all the private sector agricultural input categories. In 1975, seed research constituted a little over 5% of all US private sector agricultural input investment; by 2010, seed-biotechnology research

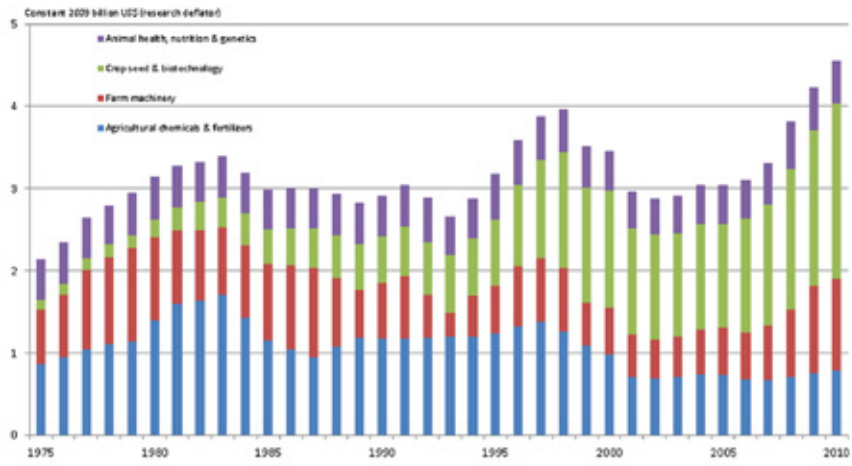

Figure 3. Seed-biotechnology research has been the growth component of all US private sector agricultural research.
Source: Fuglie et al. (2011).

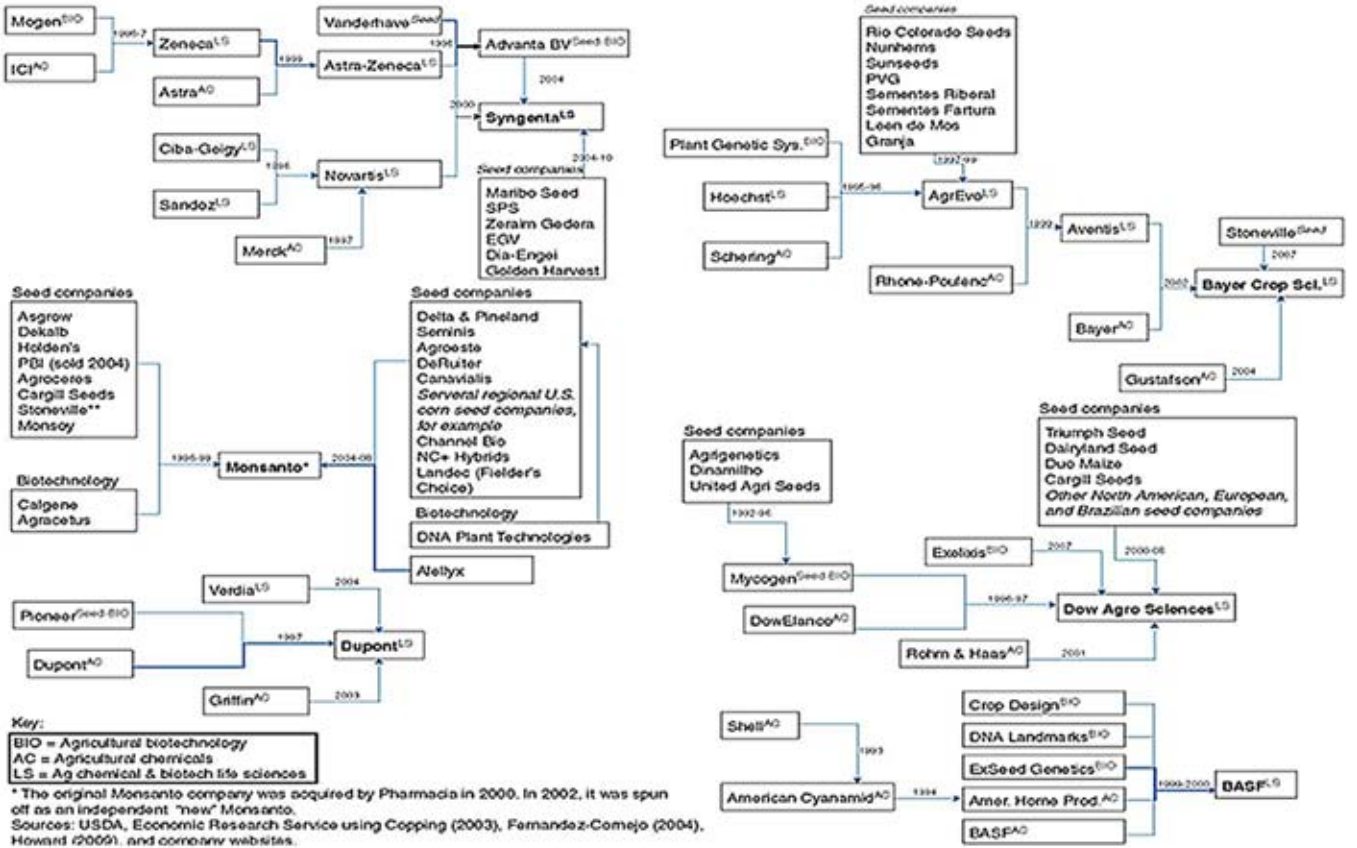

Figure 4. Formation of the "Big 6" seed-biotechnology-chemical companies. Source: Fuglie et al. (2011).

accounted for over 47% of the agricultural input total, as we see in Figure 3. By way of comparison, I used data from Fuglie et al. (2011) for the private sector and the Current Research Information System (CRIS) maintained by the National Institute for Food and Agriculture (NIFA) for the public sector to calculate some rough comparisons for 2009. In that year, the private sector spent two-thirds as much again as the public sector for *all* crop research. Private sector expenditures on seed-biotech research were over three and a half times as much as public sector expenditures on the CRIS category "genetic resources, genetics, genomics, and plant biological efficiency and abiotic stresses." It is very difficult to allocate private sector seed-biotech to particular crops, but an industry estimate that about 45% of all private seed-biotech research is devoted to corn suggests that in 2009 in the US, private seed-biotech corn research alone was seven times as great as *all* public corn research—that is, public corn research in all categories, not only those focused on genetics or genomics.

Growing Concentration in the Private Seed-Biotechnology Industry

Growth in the US and global seed-biotech industries has been marked by increasing concentration, which has also been characteristic of other private sector agricultural input industries whose research expenditures have not grown as rapidly. Globally, in 1994 the top four seed-biotechnology firms held 21% of market sales, and the top eight firms, 29%. By 2010, the share of the top four firms was nearly 54%, and the share of the top eight, 63%.

Table 1 presents more detailed data. Much of the growth in sales by leading firms was driven by mergers and acquisitions. The average annual growth in sales by all seed-biotech firms from 1994 through 2010 was about 10%; for the top four firms, the annual growth rate was 15%. Acquisitions accounted for about two-thirds of the sales growth for the top four firms. From the early 2000s, consolidation has resulted in a group of companies sometimes known as the Big 6 in the seed-biotech and agricultural chemical industries—Monsanto, DuPont Pioneer, Syngenta, Bayer Crop Science, Dow, and BASF. Figure 4 tracks that consolidation. And as we see in the statistics in Table 2, these Big 6 companies dominate various measures of research output or product com-

TABLE 1. Rising Market Concentration in the Global Crop Seed-Biotechnology Industry

Year	Four-firm concentration ratio	Eight-firm concentration ratio
	Share of global market (percent)	
1994	21.1	29.0
2000	32.5	43.1
2009	53.9	63.4

Source: USDA, Economic Research Service, based on Fuglie et al. (2011).

mercialization, including patents, field trials, GM crop approvals, seed market shares, and trait-acre market shares.

A "trait-acre" is a measure of the area sown to GM crops in which stacked GM traits are counted as multiple acres, depending on the number of traits stacked in a single seed (Fuglie et al., 2012). In fact, in the US 90% of the trait-acres can be attributed to the top firm, Monsanto. Seed share estimates for years more recent than 2007 are less certain, but it appears that in recent years the top two firms in corn, soybeans, and cotton in the US have had from 60% to over 70% of the total market share (Monsanto and DuPont Pioneer for corn and soybeans, Bayer Crop Science and Monsanto for cotton).

These changes in market structure in the crop seed and biotechnology industries have been driven by acquisition of complementary technology and marketing assets, and economies of scale in crop biotechnology R&D (Fuglie et al., 2012). Greater market power resulting from concentration may be one factor contributing to higher seed prices for farmers to pay. For purposes of this discussion, though, I will focus primarily on the potential effects of market power on innovation. On the one hand, Kalaitzandonakes et al. (2010) calculate that the value of price premiums and markups for GM corn and

TABLE 2: Measures of Research Output or New Product Commercialization Reflecting High Concentration Ratios in the Seed-Biotechnology Industry

Measure of research output or new product commercialization	**Share held by "Big 6" companies (including subsidiaries and acquisitions)**
US patents issued for all crop cultivars, 1982–2007	76
US patents issued for agricultural biotechnology, 1976–2000	64
Field trials of GM plants in US, 1985 to mid-2008	62
GM crop approvals for planting or environmental release globally, 1985-2007	87
Market share for US corn seed, 2007	70
Market share for US soybean seed, 2007	55
Market share for US cotton seed, 2007	92
Market share of trait-acres* for GM corn, soybeans, cotton, and canola worldwide in 2007	>95
Market share of trait-acres* for GM corn, soybeans, and cotton in the US in 2009	>95 (90% held by top firm)

*A "trait-acre" is the area sown to GM crops, where stacked GM traits are counted as multiple acres, depending on the number of traits stacked in a single seed.

Source: USDA Economic Research Service, using Fuglie et al. (2011) and Moschini (2010).

soybean seed in the US did not exceed R&D expenditures until 2007 and contend that this supports a claim of "dynamic efficiency." On the other hand, Schimmelpfennig et al. (2004), using field trial data, argue that increases in industry concentration have had a negative effect on research intensity in agricultural biotechnology. Shi et al. (2013) claim that concentration may favor "too much" emphasis on trait development and "too little" on core germplasm improvement.

These and other claims are complex and difficult to evaluate, but worthy of discussion. In the next presentation, Rick Welsh will address some of the issues concerning intellectual property and regulation in greater depth. Here, I'll conclude with a few notes on some observable trends that could be related to the rate of innovation in agricultural biotechnology, as well as another phenomenon—movement of some large firms towards provision of data services to aid with farm management, particularly in the context of precision agriculture.

Small and medium agricultural biotechnology firms only account for about 5% of the total research by the private seed-biotechnology industry. Nonetheless, they have been the source of some of the major innovations in the field, both for research tools and for traits. Since the early 2000s, the number of small to medium agricultural biotechnology start-ups has slowed down. Given exits from this sector, the total number of firms has begun to decline slightly from about 2002. About 75 percent of exiting firms have left through acquisition by another firm, and Figure 5 presents several graphs of those trends. Petitions to USDA for deregulation of GM crops are another indicator of activity

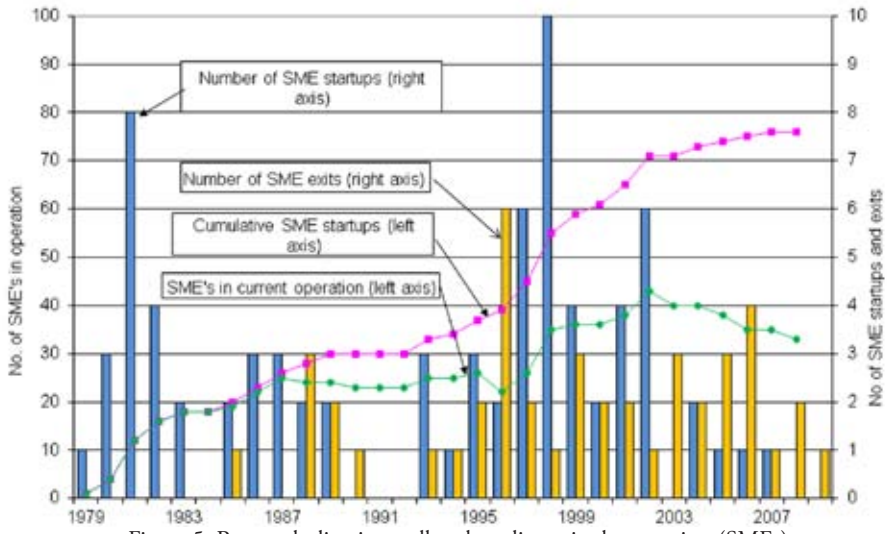

Figure 5. Recent decline in small and medium-sized enterprises (SMEs) in agricultural biotechnology.
Source: Fuglie et al. (2011).

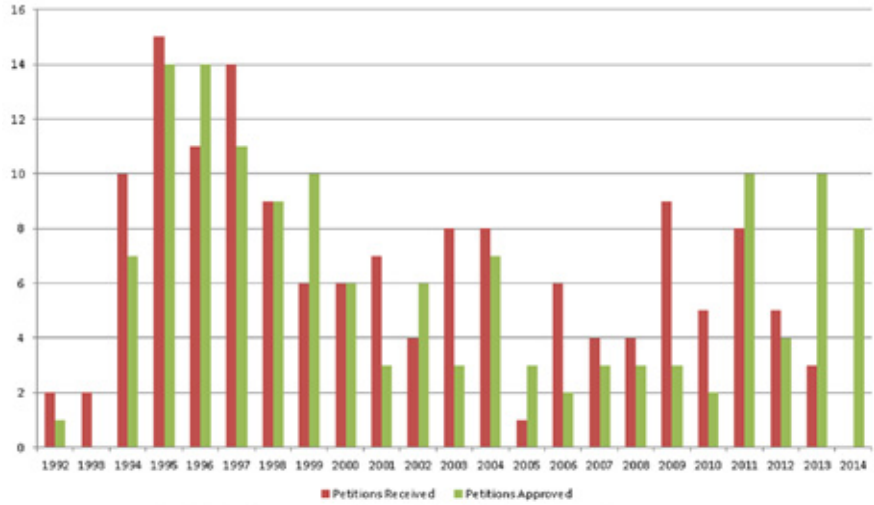

Figure 6. Trends in petitions to USDA for deregulation of GM crops, 1992–2014. Source: ISB, Virginia Tech.

in agricultural biotechnology. Annual petitions received were highest in the late 1990s; since then they have been fewer and more variable. In fact, the Information Systems for Biotechnology (ISB) database records no deregulation petitions received in 2014, although eight petitions were granted because of the lags between receipt and approval. Figure 6 shows this temporal pattern. These trends suggest the possibility of slowing in the rate of innovation.

With the purchase of the Climate Corporation for $930 million in 2013, Monsanto signaled its intent to provide a variety of data-based tools to assist farmers in their management decisions. Also in 2013, DuPont Pioneer entered into a data partnership with John Deere. These developments link large seed-biotechnology companies with tools for precision agriculture, with implications for further biotechnology innovations that are unclear. They also reflect greater investment by these firms in farm management research, which up to now has been more the province of the public sector.

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Understanding the Social Controversies over Agricultural Biotechnology

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Introduction

In sociology *social problems* are a subject of inquiry and teaching. That subject is a central aspect of any sociology curriculum at a higher education institution (Best, 2011). However, there is not a single definition of what constitutes a social problem. And, what is perceived as a social problem or not is highly subjective; that is, one person's social problem can be another person's solution to a social problem.

However, Dr. J.S. Mahoney of Virginia Commonwealth University (http://www.people.vcu.edu/~jmahoney/define.htm) argues that there are widely agreed upon criteria for whether a social problem can be said to exist. These are:

1. The objective condition must be perceived to be a social problem publicly. That is, there must be some public outcry. People must become actively involved in discussing the problem. Public attention becomes directed toward that social condition.
2. The condition must involve a gap between social ideals and social reality.
3. A significant proportion of the population must be involved in defining the problem. A large proportion of the population must be concerned about the condition—it must have national attention.
4. The condition must be capable of solution through collective action by people. If no solution is perceived to be possible, people will resign themselves to their fate.

From this perspective, the development and commercialization of agricultural biotechnologies (GM crops), or more specifically transgenic crops with herbicide tolerance or insect resistance traits, can be viewed as a social problem. I am not arguing these technologies are the cause of problems in society; rather, my point is that the intense debates

and campaigns in favor of or in opposition to these technologies rise to the definition of social problem a la Mahoney above.

It is inarguable that there is a lot of public attention on GM crops, whether the attention is favorable or not. Ballot initiatives to label GM crops have taken place in several states, including Hawaii, California, Oregon, Colorado, Vermont, and other northeastern states ((http://www.centerforfoodsafety.org/issues/976/ge-food-labeling/state-labeling-initiatives#). In addition, the geographic spread and numbers of people and amounts of money being spent on the initiatives, for and against, mean that conditions 3 and 4 are satisfied: the scope is national, and collective action is seen as a solution one way or another. Condition 2 is met because GM crop proponents see the technologies as largely beneficial to society, and opposition to them baffling or based in scientific illiteracy (Evenson, 2006; Faivre, 2015). Opponents, on the other hand, view the advent and deployment of the technologies as a highly controversial scheme to restructure the food supply for profit with dubious benefits, or even dangers, for society (e.g., Smith, 2003).

For these reasons, in this paper I will argue that GM crops can be viewed as presenting a potentially intractable social problem. Specifically, I hypothesize that

> *The development path of the agricultural biotechnology industry, including the novelty of the technologies, has resulted in rapid deployment and adoption, while at the same time created a strong resistance movement.*

That is, the very crop traits, industry structure, and regulatory approval process that have facilitated extremely rapid and extensive adoption have also created social and economic conditions and product characteristics that have engendered unease among consumers and others. This unease has proven to be exploitable by anti-GM groups attempting to develop negative images of the industry and the technologies.

To support this hypothesis, I first review the relevant court decisions that allowed and encouraged the use of utility patents in agriculture—an economic sector in which they had not been used extensively. Then I discuss the ramifications of the resulting structure of the life science industry, wherein the seed sector was integrated with the agricultural chemical sector. After this I argue that it might have been a strategic error on the part of the biotechnology industry to initiate commercialization with transgenic crops in which novel genes are introduced across species lines. This is followed by a review of the regulatory theories or frameworks of "Substantial Equivalence" and "Generally Recognized as Safe" (G.R.A.S.) that have governed the federal government approval process. Finally, a discussion of how opponents and proponents frame debates over GM crops and a discussion of several possible outcomes are presented.

Court Decisions and Intellectual Property Regimes

Ananda Mohan Chakrabarty, a molecular scientist working for General Electric, requested a patent on a bacterium that was designed using molecular techniques to dissolve crude oil and was intended to treat oil spills. His request was rejected by a patent

examiner, because living organisms were not legally defined as patentable materials. Chakrabarty appealed to the Board of Patent Appeals and Interferences, but it agreed with the original decision.

Chakrabarty then appealed to the United States Court of Customs and Patent Appeals, and it ruled in favor of his position. The appeals court held that living organisms were like any other invention. Sidney A. Diamond, Commissioner of Patents and Trademarks, appealed to the Supreme Court. The Supreme Court case was argued on March 17, 1980, and decided on June 16, 1980. In a 5-4 ruling, the court ruled in favor of Chakrabarty and upheld the patent, holding that:

> A live, human-made micro-organism is patentable subject matter under [Title 35 U.S.C.] 101. Respondent's micro-organism constitutes a "manufacture" or "composition of matter" within that statute.

The majority focused on language in the original patent act that seemed to provide extremely wide coverage. In addition, as late as 1952 Congress had confirmed this interpretation by decreeing that patents could be granted for "anything under the sun" (Jasanoff, 2008; Welsh, 2009a).

The minority argued in its dissent that Congress had specifically taken up this issue through the establishment of the Plant Patent Act of 1930 and the Plant Variety Protection Act of 1970. If the original patent act had covered living organisms, then Congress would not have been required to enact separate legislation for agricultural innovations such as improved crop varieties. Critics of the majority's opinion argued that the court would have been on firmer legal ground if it had decided that the human invention had changed in such a way that Thomas Jefferson's original notion of intellectual property and patentable matter was out of date (Jasanoff, 2008; Welsh, 2009a).

In any case, the decision held that a genetically altered microorganism can be patented. Though there was relevant earlier case law regarding plants, bacteria, etc., prior to Diamond, the general interpretation was that altered natural organisms that were no longer living could be patented (Pease, 2004 [1989]). This decision, and the subsequent J.E.M. Ag Supply versus Pioneer HI-Bred, gave plant patent applicants the option of seeking utility patents under 35 U.S.C. § 101 to protect a novel variety. J.E.M. Ag Supply versus Pioneer HI-Bred clarified things by holding that the earlier Plant Patent Act of 1930 and the Plant Variety Protection Act of 1970 did not preclude patenting of seeds and plants (Pease, 2004).

The decisions increased the incentive to research, develop, and commercialize biotechnologies, including agricultural ones. They provided a huge boost to the agricultural biotechnology industry, as firms could protect their inventions or intellectual property with patents. This is because utility patents offer broader protection than the Plant Patent Act of 1930 and the Plant Variety Protection Act of 1970. The Plant Patent Act applies only to asexually reproduced and non-tuber-propagated plants; and the Plant Variety Protection Act allows a farmer privilege (farmers can save and replant seeds) and a broader research exemption than exists currently (Glenna et al., 2015; Pease, 2004).

Commercial Impacts and Industry Structure

The court decisions noted above were extremely critical building blocks for the biotechnology or life science industry. I argue they made possible the current development trajectory of the biotechnology industry and its tremendous impacts in the agricultural sector. Specifically, patenting provided sufficient protection for agricultural chemical firms to finance a shift to a life science orientation—essentially, a shift to an integrated pesticide and seed sector. Chemical firms purchased seed companies to use seed intellectual property as the vehicle for delivering transgenic technology in agriculture (Ervin et al., 2000). This shifted the seed industry from dispersed ownership, with lots of small firms, to more concentrated ownership, with a few firms controlling the industry.

Indeed, St. Louis–based Monsanto Co. was not a seed firm until after the Supreme Court decision and now is the world's largest seed firm. And the chemical firm DuPont purchased the largest seed firm Pioneer HI-Bred. The concentration ratio of the top four firms in the newly formed seed industry is over 60%, with Monsanto controlling over 25% (http://www.etcgroup.org/putting_the_cartel_before_the_horse_2013; see Table 1). A top-four ratio of 40% and one firm controlling 25% are generally considered to define a concentrated sector. The concentration in the biotechnology industry, combined with the seed and pesticide industries merging to a large extent, has had a number of important ramifications. It has made the biotech industry a target for critics such as the ETC Group, which points out its cartel-like nature. Farmers are said to be at a disadvantage, especially given the use of utility patents in place of the less restrictive intellectual property regimes used historically in agriculture (http://www.etcgroup.org/putting_the_cartel_before_the_horse_2013).

Others have pointed to the potential to increase herbicide (especially glyphosate) use in agriculture through the commercialization of herbicide-tolerant crops. And concerns have been raised regarding environmental risks from development of resistance to glyphosate and the soil bacterium *Bacillus thuringiensis*, engineered into corn, soybean, and cotton, because of the very large acreages on which the new technologies have been planted (Ervin & Welsh, 2006).

TABLE 1: Concentration in the Seed Industry, 2013

Rank	Company	Seed Sales ($US mil)	% Market Share
1	Monsanto	8,953	26.0
2	DuPont Pioneer	6,261	18.2
3	Syngenta (Switzerland)	3,185	9.2
4	Vilmorin (France) (Groupe Limagrain)	1,670	4.8
	Total (CR4)		60.2

Source: ETC Group.

Novel Technologies and Permissive Biosafety Regulation

In addition to industry structural arrangements, the nature of the technologies themselves combined with the regulatory theories employed to review them prior to commercialization have created opportunities for critics of GM crops.

A transgene is genetic material (DNA) that is inserted via gene splicing techniques *across species lines* into the genome of a host organism's cell. And a transgenic agronomic crop is one containing novel DNA derived from an organism other than the parental seeds or in addition to the parental genetic material. The foreign DNA is incorporated early in development and is inherited by offspring in Mendelian fashion (Ervin et al., 2000; Kindt et al., 2015). Conventional breeding methods did not attempt to move genetic material across species lines. For example, using conventional plant breeding methods it is not possible to insert a soil bacterium into a crop plant such that it is manifest through the plant parts. Therefore, transgenic crops are novel technologies and likely to be of interest to consumers and others. This remains true for now at least, despite the recent finding by Kindt and colleagues (2015) that horizontal gene transfer of agrobacterium DNA has occurred without direct human intervention in sweet potatoes and probably other agronomically important crops. However, we were familiar with this mechanism previously, since we used it to deliver insect resistance and/or herbicide tolerance traits to soybean, corn, cotton, and canola.

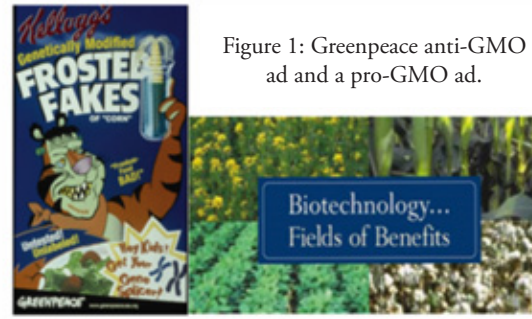

Figure 1: Greenpeace anti-GMO ad and a pro-GMO ad.

Indeed, there are other techniques to engineer crop varieties to manifest novel and potentially useful traits that are closer to conventional methods (Ervin & Welsh, 2006; Nielsen, 2003). For example, cisgenic (also intragenic) techniques might have been a more strategic approach. Cisgenesis refers to organisms that have been engineered using a process in which genes are artificially transferred between organisms that could otherwise be conventionally bred. Unlike in transgenesis, genes are only transferred between closely related organisms. A few food products engineered through cisgenic techniques are in the early stages of commercialization. And some preliminary studies look at consumer attitudes toward cisgenic crop products (Delwaide et al., 2015; also see Nielsen, 2003, for a discussion of types of transformations).

The reaction of consumers and groups that have been active in opposition to GM/transgenic crops to cisgenic crops will be interesting to see. It may be more difficult to mount campaigns based on the strangeness and novelty of the technology if it involves closely related organisms. In addition, if the findings by Kindt and colleagues (2015) are replicated widely and gain traction, it may become more difficult to campaign against transgenic crops.

However, it is clear that opposition groups have been very successful to date in exploiting the novelty of transgenic techniques to push consumers away from GM crop products (www.greenpeaceusa.org/; see Figure 1).

One reason is that critics see the US principles of substantial equivalence and generally recognized as safe as inadequate to regulate the novel technologies. Substantial equivalence means that if GE food is characterized as substantially equivalent to its "natural" antecedent, it can be assumed to pose no new health risk; GM crops are mostly the same as conventional crops, so they are treated this way by the regulatory process (Welsh, 2009b). In addition, under G.R.A.S. protocols, if a substance is generally recognized as safe under conditions of its intended use among qualified experts, it is not subject to premarket review as a food additive by the FDA, which would trigger more exacting safety testing (see http://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/default.htm). So for example, since *Bt* is used as a foliar spray in organic agriculture and is considered to have low mammalian toxicity, it is considered safe if engineered into corn and manifested through parts of the plant. That is, *Bt* is generally recognized as safe whether a foliar spray or a transgene. I argue that the perceived novelty of the GM/transgenic crops to date, combined with the use of non-novel regulatory regimes, provide rhetorical raw material to anti-GM groups.

Rapid Adoption and Resulting Push-Back

The commercialization of transgenic crops has resulted in rapid adoption globally (http://www.isaaa.org/). This is a result of the resources concentrated in the life science sector and the global reach of the firms in it as well as the popularity of transgenically derived traits among farmers. In addition, the restrictive patent protections and permissive regulatory environment have incentivized firms to move the required technologies forward and invest heavily in their success. However, I argue that these same conditions and circumstances have also created an increasingly successful backlash and resistance movement against the technologies. This is due in part to the ability of anti-GMO groups to cast in a negative light both the new technologies and IP regimes and the transformed seed industry's resulting concentration and integration with the pesticide industry. In addition, these same groups have been somewhat successful in painting the regulatory regimes employed as ineffective and as catering to the life science firms (e.g., Smith, 2003).

However, I also argue that the development path and commercialization strategy of the firms in the life science sector prevent meaningful and rigorous public debate and input. Environmental and other groups and individuals believe themselves to be frozen out of the process and do not trust the major players in the life science sector because, at least in part, of their involvement in the pesticide industry—a frequent target of environmental groups. For example, in the Chakrabarty v Diamond decision the dissent focused on the lack of provision for Congress to weigh in on such an important policy decision with far-reaching economic and social implications (Jasanoff, 2008; Welsh, 2009a).

Faced with these circumstances, groups suspicious of the new technologies began campaigns against them. Anti-biotech groups employed provocative symbols to turn

consumers away from the technologies (see Figure 1). Such campaigns are not peculiar to anti-GMO groups. In fact, they have become a common method of influencing policy when access to formal institutions such as Congress, the executive branch, and the courts are not available or have proven ineffective (Rosenbaum, 2013).

As discussed earlier, the campaigns have been successful in creating support among the general public for labeling GMO ingredients and have resulted in some state-level policies supported by anti-GMO groups and opposed by industry (http://www.centerforfoodsafety.org/issues/976/ge-food-labeling/state-labeling-initiatives#). In addition, industry has responded with its own public relations campaigns and attempts to pass legislation at the federal level to undercut state labeling laws (http://coalitionforsafeaffordablefood.org/). Each side in the debate attempts to convince policy makers and, especially, food consumers of the legitimacy of their arguments and the poverty of the opponents' arguments. In sociology, this type of social action is called "framing."

Framing is an action-oriented set of beliefs and meanings that inspire and legitimize activities and campaigns (Clapp & Fuchs, 2009). Anti-biotech groups have a shared frame. Their frame emphasizes lack of data on the safety of consuming GM foods, lack of sufficient regulations from the EPA, FDA, and USDA, and biodiversity loss due to negative impacts on non-target plants and animals (Welsh & Ervin, 2006).

Life science firms and most scientists and policy makers also have a shared frame for agricultural biotechnology. This frame emphasizes increased food security and environmental sustainability, less pesticide use, higher yields, and increased nutritional intake (http://coalitionforsafeaffordablefood.org/; and see Figure 1).

The result is a polarized dialogue, especially in the United States. What is needed is greater social consensus around technological change in the food and agricultural sector (Welsh & Ervin, 2006). This consensus will probably not be obtained through the current conflicting strategies of industry and anti-GMO groups.

Discussion and Conclusions

The development path and commercialization strategy followed by the life science industry was economically rational and very effective, resulting in rapid commercialization and adoption by farmers in the US and elsewhere (isaaa.org/). At the same time, the structure of the emergent life science industry and the perceived novelty of its technologies and IP regimes, coupled with a permissive regulatory theory, created the conditions for an effective anti-GM food campaign. At this point the outcome is unclear. If GM foods are labeled, will consumers listen to anti-GM rhetoric and turn away from them? If this occurs, GM technology might become largely irrelevant. However, it is also possible that that most consumers will focus on price and product quality and not on traits such as genetic modification. If this is the case, then consumers wary of GM foods will drive the demand for organic and other non-GM food, and the dominant issue will become coexistence. Can we develop policies and a reliable infrastructure whereby GM foods and non-GM foods can serve their respective constituencies?

Another approach would be to engage in meaningful dialogue around the salient issues. For example, industry might consider acquiescing and reverting to more traditional forms

of IP protection, such as Plant Variety Protection Certificates (see Ervin et al., 2000). In addition, to bolster public confidence and allay concerns, GM crops, at least in the short term, could be regulated under a food additive regime (http://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/default.htm). This would trigger additional food safety testing, which would raise costs but might produce longer-term sustainable economic and social benefits. These types of suggestions may appear to be far-fetched or nonstarters. However, given the effectiveness to date of anti-GM food groups in influencing public opinion, it could be time for industry to try a different strategy than PR campaigns and flexing its legislative and policy muscles.

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Figure 1: Greenpeace anti-GM food cartoon and pro GM food advertisement.

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Do American Consumers Want GM Food Labeling? It Depends on How You Ask the Question

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Good afternoon. I am a professor and chair of the Department of Human Ecology at Rutgers, the State University of New Jersey, the land grant university for the state of New Jersey. I'm an experimental psychologist, and I study public perceptions of risk and risk communication. I have been looking at public perceptions of GMOs for more than 20 years. The first paper I published was in *Nature Biotechnology* back in 1996.

I have about 10–12 minutes to tell you everything I have learned in the last 20 years. My first key point is this: The success of ag-biotech depends as much on consumer perceptions and acceptance of GM products as it does on the ability to create them. Key point number two is that most of the American public actually knows little or nothing about GMOs, and I will show you some data that illustrates that.

In 2013 we conducted a study with support from my dean just before one of the referenda on GMO labeling. We wanted to get national baseline data because we actually thought that the proposition was going to pass, and we wanted to see before and after changes.

The timing for data collection was October 23–27, 2013. This is nationally representative data collected by GFK Knowledge Networks from an internet panel recruited using proportional random sampling, currently the best way to get a representative sample. It is not an opt-in survey. The margin of error is plus/minus 3%. The data is weighted to project to the US population.

Here are some selected results:

- We asked, "Before this survey were you aware that GM foods existed?" Twenty-five percent of the population said no, indicating that one-quarter of the population has no idea that these things even exist.
- "How much have you heard or read or heard about GM foods?" Fifty percent said "very little" or "nothing at all." Half the population says they know very little or

have heard or read very little or nothing at all about GMOs. Now that comes as a surprise perhaps to many of you in this room who spend your lives studying this issue, but this is not the only data that suggests this, and frankly, the data I have collected over the last 20 years shows there has been very little change in this number.

- "How much do you know?" Fifty-five percent say "very little" or "nothing at all." So, half the population said they've heard or read very little about GMOs. More than half the population says they know very little or nothing at all about GMOs. "How often have you talked about this?" Sixty-six percent, two-thirds, never have had a conversation about GMOs with anyone in their entire lives.
- Of those who have had a conversation, only 3% of the public says they have done so frequently. So that is the most engaged segment of the population. Again, this was right before a referendum, there was a lot of press about it, and still only 3% said they've had frequent conversations about GMOs; 18% said "occasionally"; 11% said "very rarely." "As far as you know are there any foods containing GM ingredients in supermarkets right now?" Only 43% say yes, and 51% say they don't know. What I want to try to communicate to you is that, in fact, the majority of the population does not know if supermarkets are selling GMOs.
- We asked the 43% who said they knew that there are GMO-containing products in the supermarket to pick out particular products with GMO components from a list and generated the following responses: (see Figure 1)
  - For foods that are currently on the market in GMO versions: 75% think that there are GMO varieties of corn; 59% think there are GMO varieties of soybeans; 34%, canola; 47%, soy; 30%, squash; 28%, sugar, and 22% papayas. It is worth noting that while GMO varieties of papayas saved the Hawaiian papaya industry, most of that crop is exported and so most of the US population cannot actually purchase GMO papayas in their local supermarkets.
  - For foods not currently available as GMO, 56% think there are GMO tomatoes available in US supermarkets (there have not been since 1997!), and 55% think that products with GMO wheat are for sale. Fifty percent think GMO chicken is for sale in US supermarkets; 44%, apples; 40%, rice; 35%, salmon; 34%, oranges.
  - The bottom line is, 43% of the population thinks or guesses correctly that there are products with GMO ingredients on supermarket shelves. However, the majority of the ingredients they think are GMO in fact are not. So there is considerable confusion about what GMO products are available in US supermarkets.
- We asked, "Have you ever eaten a food containing GMO ingredients?" Only 26% of the population said yes. In the room here, how many of you have eaten a food with a GMO ingredient? Please raise your hands. You should know that you have all been eating GMOs for about 20 years now. Yet, only about one-quarter of the population knows that.

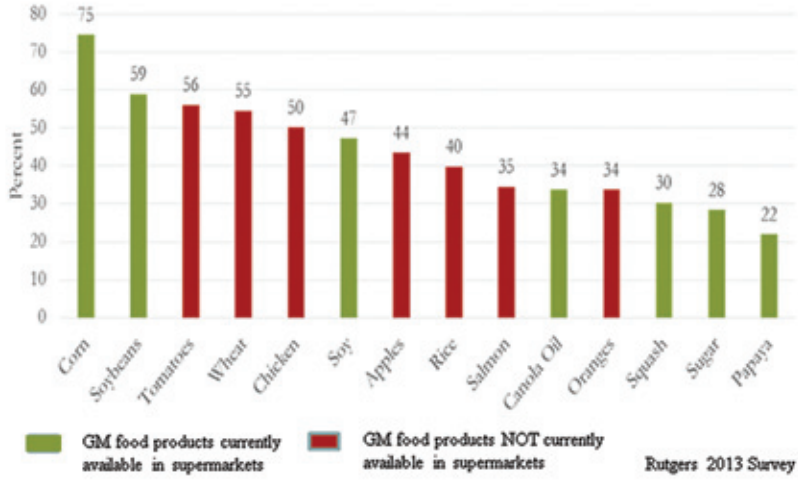

Figure 1. Percent of 491 consumers who said GM foods are available in US supermarkets. Rutgers 2013 Survey

So, here is my key point number three: Most Americans have heard, read, and talked little about GMOs. Most don't know foods with GM ingredients are sold in US supermarkets. Many of the foods people think are GMO are not, and most don't know that they are eating foods with GMO ingredients.

Key point number four is that being uninformed does not stand in the way of having an opinion in the US, or expressing it, or running for the legislature.

One of the things I will show you is that how you ask the question likely determines the answer you get when the population doesn't know anything, hasn't heard anything, hasn't talked about it, and hasn't actually made up their minds about GMOs. In the survey, we simply asked, "Do you approve or disapprove of the use of genetic modification to create new varieties of plants?" We asked the same question in regard to animals as to plants.

Seventeen percent say they approve, and of that, 5% say they strongly approve, 12% say they somewhat approve. Thirty percent say they disapprove, and of those, 14% strongly disapprove, 16% somewhat disapprove. Then there is the "I don't know response"; 50% indicate a neutral response, composed of 25% who said they neither approve nor disapprove and 25% who simply say they don't know.

However, it is important to note that most Americans will only say "I don't know" if you give them the opportunity to say it. So, one of the things to be aware of when you read the results of other surveys about public approval of GMOs is whether these surveys allowed people to say "I don't know" or only offered a forced choice of yes or no. If we take the 50% who initially say they are unsure or neither approve nor disapprove, and ask

them whether they lean toward approval or disapproval, we actually end up with another 18% leaning toward approval and about 15% leaning toward disapproval; and so what we end up with is 33% approving, 45% disapproving, and 18% neutral.

So how you ask the question largely determines the responses. If you want to claim that the majority of the population disapproves of GMOs, you can ask the question in such a way that people who don't really know the issue will seem to disapprove.

Here is key point number five from the standpoint of a psychologist: Relatively uninformed opinions are uncrystallized, which means they are not well thought through. They are not strongly held. They are subject to change and in fact they are influenced by the way you ask the questions.

Point six is that decision making involves both cognition and affect; that is, both thoughts and feelings. Many psychologists, and also the economists with whom I work who incorporate ideas about emotion into their theories, suggest that affect only comes after cognition—that first we think and then we feel. An economist might say that people evaluate the information they are given, which leads to an overall affective reaction, fear, anger, dread, outrage, and that is the way the world works. Yet, anyone who has been in love knows that very often, first we feel and then sometimes we think.

I also know as a psychologist that the way the world really works is that affect often comes first. In fact research tells us that people have a remarkably poor understanding of what actually influences their perceptions and their behaviors, their decisions. They cannot say why they feel the way they do, they just feel. They can't say why they made a particular choice. They just made it. They can't say why they acted the way they did, they just did so. And so, the question is, on what are they basing these kinds of decisions? It is pretty clear to me that affect can actually drive future cognition; we know that first impressions matter, for example. When you want to sell a house, you fix up the outside to have curb appeal, right? So people fall in love with the house and overlook how bad the kitchen actually is? There is also this kind of cyclical thinking that we are familiar with: I like it because it is good, and it is good because I like it.

Affect also plays an important role in framing the way people interpret cognitive information. Content for decision making about biotech is in fact, fairly abstract. People haven't heard very much. They don't know very much. They haven't talked about it. They don't know they are eating it. It is also not very high on the issue agenda for most people. If it were, they would actually be talking about it. And I just showed you they are not. The key thing is that this is not something about which people have been forced to make personal decisions. In fact, because we don't have a lot of labels about GMOs, people don't know that they are actually purchasing products with GMO ingredients unless they have seen one that says "GMO-free."

So, key point seven is that affect plays an important role in perceptions of GMOs. Most of the population don't know very much, haven't heard very much, aren't talking about it, and don't know they are eating it, and yet they have opinions.

What is the basis for these opinions? We asked, "Would you say your opinion of GM foods is based on general feeling or specific issues?" Our advisors at GFK said you can't ask that

question. No one will answer it honestly. However, 50% of the population said "a general feeling," which makes a lot of sense given that 50% said that they didn't know anything. Fifteen percent—*only* 15%—said that their opinion was based on "specific issues," and another third indicated a combination of issues and feelings. So the basis for opinions isn't necessarily a thoroughly reasoned argument of the pros and cons of GMOs. People don't know very much about GMOs, but what they do know is that they don't like it.

Internet hoax: KFC said one of the best known fake rumors was that chickens used by the company are genetically modified and have six wings and eight legs (computer-generated image).

Key point number eight: Even the best science can be overwhelmed by people's worst fears. Yesterday's *Wall Street Journal* featured a story with the headline "Kentucky Fried Chicken Sues Chinese Companies over Alleged Eight-Legged Chicken Growers." And you laugh, but in fact this is apparently a fairly widespread rumor in China, and according to some of my graduate students, has been around for about three or four years. And to prove that the rumor is true, there is this (obviously Photoshopped) picture of an eight-legged, six-winged chicken that has been passed around social media.

Even if you don't know very much about agriculture but you do think that Kentucky Fried Chicken is out to make as much profit as they possibly can, this can appear plausible to you. And again, you laugh, but if you have no connection to agriculture how would you know this is not possible or not even preferable from an agricultural standpoint? There is a picture of it, it therefore must be true.

This is likely the evolution of a rumor prevalent about ten years ago. The rumor then was that Kentucky Fried Chicken had changed their name to KFC because they were using chickens so genetically altered that they could not be called chicken anymore. The rumor suggested that KFC was breeding chickens that had no feathers, beaks, or feet because it made them easier to process.

In data collected in 2004, we found that a large number of Americans had heard this rumor. An even larger number of people were willing to believe it. We updated this data in 2013 along with some other things that we had seen on the internet. We asked the following true/false questions: Are GE crops harmful to bees? Does eating GE wheat lead to gluten intolerance? Was a genetically altered chicken used by a fast food company? Has

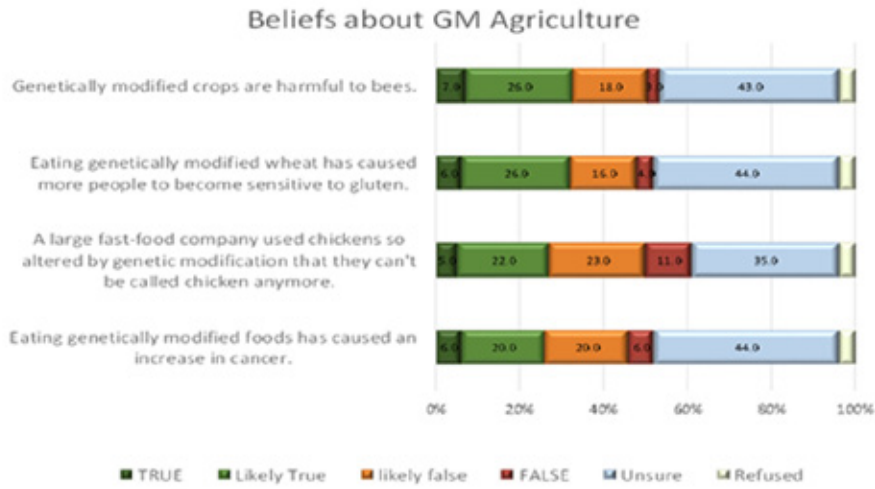

Figure 2. Decisions About the Veracity of Claims/"Facts." Hallman, Cute, Morin 2013

eating GE food caused an increase in cancer? Figure 2 illustrates the results. We formulated the questions this way because we know that Americans are really good guessers when confronted with true/false questions. In part, this is because we teach students not to leave a true/false question blank on a test because doing so means they get no credit. So, we teach people to take their best guess, and the odds are 50/50 that they will get credit. In this graph, the light green and the light orange reflect people's guesses, so perhaps you should just really pay attention to the dark green and the dark red and also the white, which is "I don't know."

Asked "Are GM crops harmful?" a large percentage of the population either says yes that is true or they don't know. Asked if eating GM wheat has caused more people to become sensitive to gluten, the same thing. Large fast-food companies used chickens so altered by GMOs that they can't be called chickens anymore? About one-quarter of the population believes that is true. Another third can't say whether it is true or false. That should be disturbing to you. "Eating GM foods has caused an increase in cancer." Again, it all sounds plausible. Given what little they know about GMOs, why should people be able to reject these particular ideas?

Key point number nine: People learn about many risks through implicit comparisons suggesting superiority. Lots of advertising introduces risks that people have never heard of before or implies that what is "free" is best. We have "cage-free," "antibiotic-free," "cruelty-free," "BPA-free," and my favorite, the impossible "chemical-free." GMOs are often framed as though they were a contaminating substance, not a range of technologies. So "GMO-free" suggests that a product is free of a particular contaminant, as opposed to being free from an ingredient produced through a particular technology.

My colleague Mr. Welsh was talking here earlier about framing. Here is Chipotle, which is very, very disturbing, saying they are "GMOver it" and using the frames Dr. Welsh just discussed for why they made this decision. Hershey has plans to produce chocolate without GMO ingredients, which has been framed as having been in response to pressure from anti-GMO activists. In fact this development is portrayed in the anti-GMO activists' press releases as a victory. And then finally we have Similac, which just introduced a non-GMO formula. Why is this important? Because once people make a decision to purchase one of these products, their opinions become a lot more crystallized. And then they actually adjust their attitudes and opinions to support that decision. They pay attention to confirming information. They discount inconsistent information. More maddeningly, they reinterpret disconfirming information to support what they already believe and they take actions and make other decisions that support their initial decisions.

So, that is all I have time to say. I hope you will ask me good questions.

Speaker Profile: http://humanecology.rutgers.edu/faculty.asp?fid=28

Stephen Palacios presented *The Limits of Science in Impacting the GMO Discourse: How Food Manufacturers and Retailers Affect Consumer Opinion*, but elected to not have his talk published in this report.

Social and Economic Dimensions of Sustainability

Q&A

Moderator: Leland Glenna

Glenna: I was a pastor before I became an academic, and in my sermon training as Lutheran pastor I was taught to point out that no one should feel morally superior. We all know that the public is somewhat misinformed, in fact they actually are wrong about a lot of things. But I will just suggest that we are, too. All of us in this room are just as ill informed on many topics. Maybe we think we know a little bit more about this particular subject, but at any given time we are also misinformed. The discussion yesterday, the back and forth about regulations, indicates there is more ideology in this room than I think we might like to admit.

R. Roush, Penn State: I want to make a comment about Rick Welsh's suggestion to move the registration process into food additives area. Oils, for example, don't have food additives. They don't have any GMO component. It doesn't solve the problems, and unfortunately the really good ideas you had have all failed summarily in trying to persuade anybody. They are good ideas, but we have already tried them. The bigger issue with turning this thing around is that we need to be more aggressive in knocking the likes of Chipotle off their perch every time they make misleading statements. There has been a consumer revolt against the anti-vaccinators, right? I'm wondering if there are lessons from that we can hitch ourselves to in trying to point out that this is an anti-science movement.

Welsh: I have to agree. I don't think we should try to relax the IP. The damage tolerance for projects that are being worked on but are not widely commercialized yet gives them staying power. I just saw a recent study on willingness to pay for transgenics. It was close, but the point is someone is looking at it.

R. Roush: I have had debates with several anti-GM campaigners and told them about mutation breeding, so they wanted to start regulating that too now. Their very clear response was that no matter what technology is used, if it's not traditional it is not acceptable. Look at the consumer trial a few months ago, a vitamin A trial that is not connected with any multinational company, that does have consumer benefits even though they are disputed, and it was destroyed in the Philippines at the same time as somebody started chopping down papaya trees in Hawaii that have been there for years. In Australia we actually worked on an arrangement with Monsanto where farmers can keep seed. There were good reasons for it since it helped to avoid weed seed being moved around seed plots. Anti-GM groups rejected and didn't even accept that it was worth considering. Isn't that fundamentally what is driving it?

Welsh: You are right and you are not right, because there are groups who will never agree, no matter what you do. When I talked to the Union of Concerned Scientists, I asked what they wanted, and they told me that one way to improve the situation would be to treat it as a food additive. That is where that came from. But I know you don't accept it, and I conceded in my talk that going that route might not make any difference at all. I am just saying that part of my talk was based on rhetorical frames being used as a way for discussing resistance. And I am speculating about some approaches that might untangle things.

Heisey: I wanted to throw out one little thing, but I don't know if this will work for Rick Roush, either. One of my daughters has Type 1 diabetes. Genetic engineering basically keeps her alive, so you could ask if anti-GE folks want us to go back to using pig stomach insulin for treatment of that disease.

R. Roush: The response to that is, that is a choice a person can make for themselves, but GM food has been forced on the consumer. You don't seem to split many people off. I accept what you are saying, but I am looking for even bigger wedges.

W. Kerr, University of Saskatchewan: I spend a lot of time in Europe eating, and I see a psychological perspective. If I were to ask Europeans if they would eat GMOs, a universal no would be the reply, and I would become a social pariah if I were to actually admit that I would eat them. Rick, does it eventually get to the point of this acute social dimension?

Hallman: There are a couple of things I want to say about this. There is a major difference between the European and the American view of GMOs. We actually did some cross-cultural work a number of years ago in which we did face-to-face interviews with school teachers in the US and in Germany, and we essentially had a set of open-ended questions. At one point we described an apple that that would not brown as quickly. This was ten years ago. The American school teachers by and large said, "Oh, that's really interesting, when can we buy that?" The response from the German teachers was essentially, "What's wrong with what we already have?" And that pretty much sums up the viewpoints of the two societies. A second issue is that there is a social dimension to this. People define their identities by the kinds of choices they make. It was Brillat-Savarin who said in 1826 that you are what you eat. That is so true. People are identifying themselves as vegetarians, as vegans, as organic.

It becomes a lifestyle decision, not simply "What are we going to have for dinner tonight?" The third thing is the differences between US and EU production. It appears as though Americans and Europeans have a different sense of the division between agriculture and nature. If you ever had an opportunity to do hiking in Germany or France or England, you know that many of those countries have laws that will allow you to cross a farmer's field in order to continue hiking. So you have this unsettling experience as an American of coming up to a gate with a very large bovine staring at you, and signs in eight languages: "Please Close the Gate." You walk across the field, the cow of course doesn't move because it has seen a zillion tourists go past, you come to the other side and there's another sign that asks you to close the gate. If you ask Americans where they go to recreate, to experience nature, they will by and large tell you they go to a park, which is a place set aside, separate from agriculture. In the European Union agriculture is set in the middle of nature. It is part of nature. And I think that that really strongly affects the way that people think about this.

R. Giroux, Cargill: This question is for Steven Palacios. I think a lot of what you said is not a wet blanket. I think it is an emerging reality for companies and US consumers and so I am very much interested in the idea of migrating the frame. From your perspective, what are the key levers that will help migrate that frame? All those are your customers and they are our customers. So when we talk to them about non-GMO solutions for example, we always try to frame it as a trade-off. Do we ask if we are going to go non-GM or are we going to trade off our sustainability goals, which one is more important to you? Do you have other examples?

Palacios: I think that is exactly the way to think of it. In the Chipotle example they traded off GMO for non-GMO. They didn't trade off herbicide. They didn't trade off insecticide. So what was the trade-off? The trade-off was nominal. The trade-off was emotional, and for what purpose? The purpose was to give a perception without validating it through any practice. From my perspective, pointing out what those trade-offs are and their situational context is exactly the way to go. Having one-sided discussion about whether it is bad or good is a losing proposition in GMO's history. It is my opinion that you need to pick your starting point. You say this is what GMO is providing versus an alternative way of growing and this is what GMO is providing versus an alternative way of marketing. This way you allow someone to have an educated discussion and debate. That to me is the correct path. It has to be contextual. Going back to the vaccination comment as an example: You pick the best and most popular examples people can intuitively understand to start that discussion. Then, all of a sudden, the discussion starts to change. At least I hope so.

S. Fleischer, Penn State: I agree with the speakers that the anti-GMO movement is sophisticated, is well developed, has a long history, and is quite successful. I would like to learn more about them. What is their strategic planning? They don't decide on these targets at random. There seems to be more anti-GMO discussion aimed at certain aspects of potential biotech than others. For example, I don't hear a lot about anti-GM cotton or biofuels, and potentially trees. So why are they doing what they are doing from a strategic point of view? Is it important to their financial bottom line? Do they have reasons why

they aim at certain targets versus others? And a second follow-up question is how might that influence innovation and development of products that might prove to be useful?

Welsh: Primarily, all the groups I communicate with, talk to, and have done research on are really not focused on genes. They are aimed at particular corporate actors and an industry they see as out of step, as wanting to control the food supply in ways that benefit the industry and not the consumer. You don't eat cotton, you wear it. It is harder to make the argument that this is somehow going to penetrate through me and damage me. It is much easier to take aim at the fish gene or the tomato. That is the most effective strategy. Do most consumers who eat organic do it for environmental reasons? No. They do it for health reasons, real or not. That is their motivation.

B. Gwinn, Ohio State: Early on in the conversation I spoke about public investment in research. A quick calculation: If you take corn and bean acres across this nation, pick 1% of the variable costs you end up with of about $2–5 an acre, that would be $350,000,000–$500,000,000. If you could get producers to invest an additional $5 per acre into research, that would provide an enormous amount of research dollars. Any suggestions as to where or how you might encourage that amount of public investment into research?

Heisey: I will respond and some of the other speakers might have other ideas. This again reminds me of cultural differences. In this country we have a long history of producer check-offs for market. We think that we need to spend our dollars on selling our product. In countries like Australia there has been a fairly long history of check-offs for research of the type that you suggest. I think it is certainly a direction that is well worth going. Some other economists, Julian Alstan and Richard Brey in Canada, have looked at how we can move toward supporting more research, and it should definitely be on the policy agenda.

M. Smith, Cornell University: I wanted to thank you all because this is a fascinating panel. I get to give a lot of public talks about genetically engineered crops, and I use results from several of you up there on the podium, so I thank you personally. As a professor at a land grant university, I view my role as helping to educate people, telling them what we know about this technology, what it is, what impact it has had, what we don't know, rather than telling them what to think. But every time I listen to this kind of a discussion, or when I recently listened to one of our faculty members talk about risk communication, the message I get is that more information is just not relevant and not useful. I find that very discouraging, but the invitations to speak just keep coming in. So why should I bother to do it? For somebody who is really a plant breeder, what is it we should be doing to try and help that portion of the public who isn't yet crystallized on this issue? I know what I have got to tell people who already have crystallized their thinking. That's pretty apparent. But what is it that's useful for the rest of them?

Palacios: I think for a generalist audience of that nature a certain level of education will bring benefit because now you are introducing a different understanding. Then you need to take those examples and put them into a practical trade-off analysis. We could do this or we could do that. We chose to do this for these reasons and these benefits. Use examples

that are familiar to an average person, that are experienced by an average person. Part of the anti-GMO success is picking on things that every day people use in the course of their lives and saying, "You don't want to spread that hummus on that particular cracker."

Hallman: I absolutely agree with Steven that a certain amount of information is important—it is just not enough. That is what we are saying for most populations. Part of the discussion has to be about values. We are both in land grant universities. A hundred years ago, when people were much closer to the farm and hybridization was taking place, it was actually on the front page of newspapers, because people understood that an increase in yield or insect resistance was a big deal for farmers' livelihoods. People don't understand that anymore. So the discussion first has to come down to what we all agree on are problems worth solving. The next question is, are they worth solving by using GMOs, or nanotech, or synthetic biology, or any other technology applied to agriculture? We are not actually having that discussion about the basic values, the basic problems that need to be solved. We are just telling them to trust us, that it is safe, that we are solving the problem this way.

Glenna: Dave Mortenson talked yesterday about the bioethics discussion here on campus, how packed it was, and how philosophers argue that you need to start with cases that are based on values. Putting it in a philosopher's perspective, you start with those cases to draw people in and ask what the fundamental ethical challenge here is. Then we can have a conversation. And within that context, people's values change. People's knowledge adjusts. It is really a very different way of thinking about education. This is why philosophy courses are so much fun, even though most sociologists think ethicists are kind of dry. It is a different way of looking at our approach, and it really came through in that bioethics talk. As Dave pointed out, it was standing room only and there were more people online. It was a very exciting feeling in the whole room.

C. Keene, Penn State: This question is specifically for Bill, but if others have thoughts on it I definitely want to hear them. Thinking about affect, emotional engagement and response: As an American in this room, you probably have eaten GMOs in the last 20 years, or even a lot of them for 20 years, and if you don't know anything about it, that could sound really scary, especially if the message is very easily accessed. I was wondering if that is something that can be mitigated

Hallman: That is a really, really good question I don't have a really good answer for. Twenty years ago I was saying and writing that I thought we needed to be much more transparent about getting GMO ingredients into the marketplace. The bet then was that if we simply didn't tell people and allowed them to eat it they would be fine with that. I argued then that that might actually backfire. If people learn that they have been eating something they didn't know they were eating, that might be very troubling to them. And I showed you on one of those slides that there is a significant set of the population who already believes, for example, that a lot of the gluten allergies out there are because of GMO wheat, which of course isn't on the market. One of the other things I research

besides attitudes to GMOs is attitudes to such claims and people's explanations for them. They will take whatever is the largest thing on the horizon in their experience, and they will ascribe their symptoms to that particular thing. So it is not at all surprising that when people learn they have been eating GMOs for a really long time they ascribe their problems to that. We tried to get USDA money to actually study that question and have not been successful thus far.

R. Connolly, Penn State: I think, Bill, you may have answered part of my question already. Your graph with all the different foods that could potentially be GMO and most people got it wrong reminded me of a poster I saw in a grocery store circular advertising their "non-GMO strawberries." How is that even legal?

Hallman: It is actually not.

R. Connolly: Exactly, but would GMO labeling possibly just shut people up, and what would that look like in the marketplace, considering that there are currently only about nine possible ingredients that would apply to. How would that look?

Hallman: We are asking USDA to give us the money to take a look at this. There are a number of labeling and post-labeling schemes in at least 36 states. Each has different language, a variety of different terms, and a variety of different products that they would apply it to. It will be interesting to see what will happen if a number of them pass. How will people react? I think it will depend on what the particular products are. From an affective reaction, I would think that when people are purchasing products because of their particular health benefits—or their perceived health benefits—non-GMO might in fact be more important than if they are buying snack cakes, because no one is under the illusion that Twinkies are good for your health. So what if they are GMO-free or if they contain GMOs? I think there will be different labels, either claiming non-GMO or stating that the food contains GMO.

C. Mallory-Smith, Oregon State University: I want to follow up on the comment about growing opposition among scientists, and so I would like to know what you are basing that on?

Welsh: I don't know if it is growing opposition as much as it is seeing the tea leaves or moving in a different direction. I am basing that statement on my experiences as editor of *Renewable Agriculture and Food Systems*, formerly the *American Journal of Alternative Agriculture*, which has been acquired by Cambridge University Press, and now our submissions are going off the charts. I am adding associate editors all the time, and people interested in reviewing papers, and these are all very well published mainstream scientists. Our impact is growing very quickly for an ag journal. We are not anti-biotech by any means. My people in the organic community say that I am soft on biotech. Our journal generally looks at different approaches to agricultural production. It is almost entirely focused on production, things like soil quality, nutrient content, cover crops, biodiversity, crop diversity, all these kinds of approaches, and there just are not that many biotech publications you can publish in. That is what I am basing my statement on.

A. Ponce de León, University of Minnesota: I have a question for Bill. You showed us statistical data on perceptions or level of knowledge in our population. Have you also analyzed statistics on cost levels and perceptions? I would like to put the question to all of you if this is a good time to revisit discussion about the level of education that we are providing to our youth, not necessarily for influencing decisions but at least for providing basic information?

Hallman: The answer is yes, we have looked at demographic predictors of public opinion and who knows what. Not surprisingly, men claim to know more about almost everything. I can show you the data: If you follow up with real questions about real science, they don't actually know much more than their spouses. In terms of age, it is not exactly what you would expect. People who say that they are most actively avoiding GMOs tend to be in the middle of the age spectrum, especially parents with children. People who are older and younger seem to be more open to GMOs. If Steven indicated that he was a wet blanket, I am going to be the fire extinguisher. I do research in risk perception and risk communication, not just about GMOs but about lots of other things like nanotechnology and toxicology, and because I sit on an FDA panel I deal with drugs and medical devices. I am asked frequently to talk about risk perception. I am usually on the last panel, because, as we all know, that is where the social scientists should go in case anyone needs to catch their plane. And generally speaking there is a lot of talk from the scientific community that we need to get our particular science into the classroom. If people just understood the facts, everything would be fine. The truth is, that is not the way it works. And good luck trying to get anything into a curriculum. Those of us who have extension appointments will tell you it is nigh impossible to do that. Curriculums are very well regulated. There are teachers who want to teach things on their own who can't actually do it. And pretty much every science wants to be introduced in the classroom. So if you are a chemist and there is a toxicology issue, the solution of course is to teach kids more chemistry. If you are a biologist you want them to know more biology. I've done work on electromagnetic fields because physicists want kids to learn more about how electricity works. The truth is, we can't simply turn students into mini-experts in every scientific field. We have to figure out ways to communicate with the public outside that line.

Glenna: Let me shift away from knowledge and education. Why should we trust scientists? Why should we trust the publicists? Why should we trust the regulatory agencies? We heard yesterday about herbicide resistance. Scientists were sounding the alarm about herbicide resistance to glyphosate for years. The regulatory agency just pushed the agenda through. We now have resistant weeds. Why should the public trust anything we say or anything regulators say?

Welsh: We have been talking mostly about how we are going to convince people to stop thinking how they are thinking. I believe that is not going to work. We also need to take a look at some of the things we scientists say. I was reading the NRC Report on Ag Biotech 2010, and what struck me was the variability and uncertainty in yield increases around the world from biotech crops and how difficult it was to tell if there were increases and

where they occurred, and a lot of variables seemed to go into that. It gave me pause, and I thought that it is going to be hard to make a "feed the world" argument based on the numbers being published by the National Research Council.

M. Kahn, Washington State: Just a follow-up on some earlier discussions. When the labeling initiative was put on the ballot in the State of Washington, alcohol was specifically excluded. As a scientist, it seemed to me that high-fructose corn syrup from GMO and non-GMO is pretty much identical, whereas I can imagine the bourbon from GMO might be different because of the secondary products in bourbon from non-GMO. But the anti-GMO groups had made a strategic decision not to engage the alcohol market in the discussion. They had exempted alcohol from this. So in retrospect I think that if the people who were against GMO labeling in Washington had insisted that you apply uniform standards—if GMO corn is no good in one place, then it should be no good in Maker's Mark—then you would have changed the way in which that went to the ballot. And I think one has to get back into the details of how these questions are phrased in order to understand just exactly where people are coming from.

Hallman: I would propose the task of a taste testing of GMO bourbon.

PART IV–BANQUET AND LUNCHEON PRESENTATIONS

AC21—The Journey to Coexistence

Russell C. Redding
Pennsylvania Secretary of Agriculture

On behalf of Governor Tom Wolf, welcome to Pennsylvania and Penn State. I'm honored to participate, and appreciate the good work of the North American Biotechnology Council. Thank you, Council, Dean Roush, Dr. Gary Thompson, and the planning committee, for the invitation to address the conference. It is a privilege to be here.

I also want to acknowledge former Undersecretary Merrigan for her leadership and public service generally, and specifically on USDA's AC21, the Advisory Committee on 21st Century Agriculture. To Committee members Lynn Clarkson and Greg Jaffe, thank you for good work and perspective. To Dr. Michael Schechtman, your leadership and skills are extraordinary. Thanks for making them available to AC21.

When I first met Governor Wolf, we discussed agriculture and the food system, and he described it as a natural resource and economic resource. I thought this was a great way to frame agriculture's responsibilities to society and captured society's expectations of us. I was struck by his depth of knowledge of agriculture and the influence his Peace Corps years in India, working with a small village on a new rice variety, had on his belief that agriculture can change lives and communities, and his belief in the power of science. It was this discussion and his respect for public service that convinced me to serve again as secretary. Together, I believe we can do great things.

Opportunities and Challenges

As you know, these are extraordinary times in agriculture and government—full of opportunities and challenges that require all of us to be engaged, constructive, and prepared to listen, learn, and lead. One of those issues that appear in both the opportunity and challenge column is biotechnology. "Biotechnology: Opportunity/Challenge" was actually the title of a 2003 AC21 report. With this conference's focus on stewardship and sustainability, we encounter more words that appear in both the opportunity and challenge

columns. The many issues surrounding biotechnology certainly support the need for an AC21 to tackle some of the big agriculture biotechnology issues.

AC 21: A Journey

It is always difficult to know where to begin and end with any discussion about AC21 because we all make a lot of assumptions about what people know about biotechnology and the same is true for AC21, so a little background is probably helpful. I chose my words for the title tonight carefully, with emphasis on the word "journey," understanding that the work of AC21 reaches back nearly 15 years. It is also in recognition that the current work the Committee is engaged in is built on the foundation of earlier Committee deliberations and reports. And most importantly, this emphasis is a recognition that the work on coexistence continues. It has been and will continue to be a journey, because of the evolving science and practice of agriculture.

Key Issues

One of the things I was struck by when joining the Committee was the structure in place to support our work. I wasn't expecting the framework, but have come to appreciate its importance for defining scope and governance. The first element of this framework is that the AC 21 Charter from USDA names multiple roles and expectations, including the development and utilization of beneficial new agricultural products, including those derived through biotechnology. Then, second, the AC21's bylaws charge the Committee to examine the long-term impacts of biotechnology on our US food and agriculture systems and USDA. It is also to provide guidance to USDA on pressing issues, as identified by the US Secretary of Agriculture, related to the application of biotechnology in agriculture.

Agriculture Secretary Thomas Vilsack asked three questions highlighting key issues: (1) What types of compensation mechanisms, if any, would be appropriate to address economic losses by famers in which the value of their crops is reduced by unintended presence of genetically engineered material(s)? (2) What would be necessary to implement loss compensation mechanisms? That is, what would be the eligibility standards for a loss, and what tools and triggers (e.g., tolerance, testing protocols, etc.) would be needed to verify and measure such losses and determine if claims are compensable? (3) What other actions would be appropriate to bolster or facilitate coexistence among different agricultural production systems in the United States?

So the overarching issue here is this: With the growing complexity and diversity of US agriculture, how do we enhance coexistence between different forms of agriculture production?

Recommendations

The 2014 Committee brought a package of recommendations to USDA for consideration:

- Educate farmers and others in the food and feed production chain about the importance of coexistence and their roles, particularly with reference to stewardship, contracting, and attention to gene flow.

- Provide farmers with tools and incentives to promote coexistence through USDA farm programs and coordination with other entities.
- Conduct research in a range of areas that are integral to understanding the current state of coexistence and gene flow management, as well the development of improved tools and practices to manage coexistence in the future.
- Provide increased assurance about the quality and diversity of US seed and germplasm resources.
- Provide a framework for the establishment of a system of compensation for actual economic losses for farmers intending to grow identity-preserved products, if the Secretary determines loss data justifies such a step.

Coexistence

Through the Committee's process, what became clear was the issue of coexistence embodies so many fundamentals of the business of agriculture: choice, science, markets, policy, management, consumers, compromise, and change, to name just a few. But change can be difficult. Always painful, it means leaving things behind, changing habits and expectations, and experiencing stress and uncertainty. But change can also be exciting. My belief is that people will willingly put up with pain, but only if going forward is a more attractive option than staying in the same place.

So, to put AC21's deliberations into a few of my own words, this is where we are with coexistence: Coexistence is not a new practice in agriculture, nor has it failed in recent times. Farmers have the right to make the best production choices for their farms—organic, GE crops, IP, non-GE, and new functional traits. It is important that all farmers show respect for their neighbors' ability to make different production choices. And all participants in the development, breeding, marketing, and management of crops need to be involved in making coexistence work.

The number and scope of opportunities for differentiated products and markets have increased, and mechanisms for precisely evaluating the composition of products have become widely used in the market. The best situation is where good stewardship leads to effective coexistence. Prevention of a problem is preferable to dealing with negative consequences downstream, either on the farm or in the marketplace.

Implementing the Recommendations

USDA actions to implement the Committee recommendations are of the highest importance. Thank you to Secretary Vilsack and Dr. Schechtman for advancing the recommendations; some are in motion now, while others are planned. The AC21 Stakeholder Workshop in March was a significant step forward and confirmation the USDA is serious about finding solutions that promote coexistence. Some specific actions:

- Improve crop insurance for organic producers.
- Support the organic seed finder database.
- Continue or begin research projects, including control of corn pollen germination; crop stewardship and gene flow; and gene flow in alfalfa.

- Establish a National Genetic Resources Advisory Council.
- Develop an approach for examining trueness of type in the USDA National Plant Germplasm System.

Support for the Report

The best indicator the journey will continue are the signing statements members could submit to qualify their support for the report. Support falls into four categories:

Responsibility
GE material needs to be contained. Any solution that disproportionately places responsibility on certain stakeholders will increase conflict. All stakeholders have responsibility. Shared sacrifice—shared responsibility. Allow farmers to avoid what they don't want and get what they do want. Tech providers—prevention-based coexistence must protect the integrity of US ag.

Regulatory
When USDA grants nonregulated status approval to GE crops, propose coexistence measures. Some suggest making stewardship practices mandatory by embedment in contracts. Contracts with farmers should include coexistence measures, much like the restrictions that protect IP, limitations of seeds for research, insect resistance management.

Germplasm
Preserve choice—seed germ plasma protection. Non-GE seed purity and supply. Issue of adventitious presence for non-GE, organic, GE. A strong ag is a diverse ag. Must support diversity.

Transparency
Set a threshold (or trigger for adventitious presence) so everyone knows the boundaries: maintain market integrity and buyer confidence.

Impacts and Implications

These include:

- Advance the conversation about how we manage the increasingly complex landscape.
- Enhance neighbor-to-neighbor relations, contact, respect, and accountability.
- Allow farmers to place their energies and resources into productive activities and help maintain positive views of American agriculture.
- Provide incentives to develop joint coexistence plans.
- Spawn creative policy discussions about how to use public and/or private investments to achieve multiple goals important to farmers and consumers.
- Help to maintain the integrity of products and confidence of consumers (domestic and global).

- Help minimize disruptions to functioning markets at home and abroad.
- Demonstrate that coexistence is a shared responsibility and a core principle of production agriculture in the 21st century.

To conclude, coexistence is about finding solutions, not differences. Agricultural production is complex and will continue to grow in complexity. We need to figure this out for the benefit of farmers and consumers. Diversity is our strength.

Speaker Profile: https://ballotpedia.org/Russell_Redding

Sustainability of Genetically Engineered, Insect-Resistant Crops: A View from the Fringe

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The goal of this paper is to highlight important benefits and limitations of ubiquitous technology-based approaches to pest control that are often utilized outside the framework of integrated pest management (IPM). Particularly in Pennsylvania and other states on the fringe of the Cornbelt, where pest pressures can be lower or different than in large portions of the Midwest, farmers and pest managers would benefit from remembering the tenets of IPM, which involve understanding local pest populations and using appropriate measures to control them when necessary.

Introduction

When viewed from a distance, modern agricultural production can seem very uniform and generic. Particularly for grain and forage crops, there can be a perception that farmers all follow the same script, planting similar crop varieties on similar dates, and using refined management practices that result in ever-improving yields. This perception is perhaps enhanced by looking at large farms, particularly in the American Midwest, that grow grain crops over thousands of acres, dominating the landscape of some midwestern states. Eighty-six percent of land in Iowa, for example, and 75% of Illinois, are planted to just a few crop species, mainly corn and soybeans. These midwestern agricultural landscapes can generally be characterized as having little noncrop habitat and larger farms that grow a relatively limited diversity of crops with little rotation.

By contrast, only 14% of Pennsylvania is planted to crops. Pennsylvania farms are smaller and have smaller average field sizes. Moreover, Pennsylvania crop landscapes are typically much more diverse than most midwestern agricultural landscapes, containing higher levels of crop diversity and substantial areas of noncrop habitat. Also, Pennsylvania farmers tend to be more committed to longer crop rotations and conservation-based farming tactics such as

no-till and cover crops. Pennsylvania farms, and those of other mid-Atlantic or northeastern states, are therefore different from midwestern farms that form the heart of the Cornbelt. Pennsylvania is part of what can be considered the eastern fringe of the Cornbelt, and being on the fringe has costs and benefits. One of the costs is that the agricultural industry, particularly the big companies with a national scope, consider Pennsylvania and the Northeast somewhat of a secondary market; therefore, most of their products are designed for the heart of the Cornbelt, but can be used on the fringe. Among the benefits of being on the fringe is that we have lower levels of agricultural intensification, which includes lower concentrations of agricultural fields and more noncrop habitat. From a pest management perspective, lower intensification on the fringe tends to translate to lower, and occasionally different, pest populations challenging our crop fields.

IPM has historically been the dominant framework for developing pest management strategies and tactics and directing pest control decisions. Over the past two decades, however, the agricultural industry has invested in developing tools that allow farmers to protect many acres of crops by planting specialized seeds (and committing to some associated tasks), producing remarkable efficiencies. For instance, weed management was revolutionized by herbicide-resistant crops, which allow herbicides to be sprayed directly over crops. This genetically modified technology has saved farmers untold hours by simplifying weed management, but unfortunately yield improvement has not accompanied the gains in efficiency (Gurian-Sherman, 2009; Shi et al., 2013). In contrast, transgenic, insect-resistant crops (i.e., *Bt* crops) have improved yields slightly while saving farmers scouting time and insecticide costs (Gurian-Sherman, 2009; Shi et al., 2013). Because these transgenic pest management options tend to make farming easier, they have been widely adopted and are now the "default setting" for most US growers. In 2013, transgenic herbicide-tolerant corn accounted for 85% of US acreage, whereas 76% of US corn was planted with *Bt* varieties.

Building upon these seed-based pest management tools, agricultural companies have been adding further pest management options to crop seeds, widening the spectrum of insect pests that seed-based technology can control. Since 2004, the great majority of corn seed sold in the US has been treated with fungicides and/or insecticides to combat early season pathogens or insect pest populations. The insecticides used to coat seeds are from a class of compounds known as neonicotinoids, which are among the most active insecticides yet discovered, but they have been the focus of much attention recently because of their environmental contamination and potential nontarget effects (Bonmatin et al., 2015; Chagnon et al., 2015; Hallman et al., 2014; Hladik et al., 2014; Krupke et al., 2012; Main et al., 2014).

While seed-based insect management options have become standard for many growers, their value depends largely upon the size of the pest populations they are targeting. If weed populations disappear, for example, what value do herbicide-tolerant crops provide? As mentioned above, the fringe tends to have lower, or different, pest populations than the core of the Cornbelt. The goal of this paper is to highlight benefits to be gained by understanding the local pest complex and the threat posed by local pest populations. By highlighting three pest species, we will explore the value and limitations of the current "standard" approaches to pest management.

European corn borer, *Ostrinia nubilalis* (Hubner) (Lepidoptera: Crambidae)

Historically, European corn borer (ECB) has been the most important pest affecting corn production in the United States. ECB is a highly polyphagous pest species that was accidentally introduced into North America in the early 1900s (Vinal, 1917). Prior to introduction of *Bt* corn hybrids, ECB caused crop losses that annually approached $1 billion nationwide and $35 million in the Northeast (Dillehay et al., 2004; Hutchison et al., 2010). In 1996, agricultural companies introduced *Bt* corn hybrids targeting ECB. These hybrids have been widely adopted because they are exceptional for managing ECB: 99.9% of larvae are expected to die when they feed on plants expressing *Bt* toxins (Huang et al., 2011). Because of this strong efficacy, large portions of the Midwest have experienced large-scale reductions in populations of ECB (Hutchison et al., 2010).

With this previous research in mind, and seeking to understand the threat posed by ECB to Pennsylvania corn fields, colleagues and I initiated a three-year study (2010–12) to quantify ECB populations and track the yield and overall economic value of *Bt* and non-*Bt* corn hybrids. We found that *Bt* hybrids continue to provide excellent control of ECB. Moreover, in contrast to a similar study conducted in Pennsylvania in 2000–02 (Dillehay et al., 2004), we found that ECB populations in most of parts of Pennsylvania are considerably lower than ten years ago (Bohnenblust et al., 2014). This population decline may have been caused by widespread adoption of *Bt* hybrids, but our analyses did not detect a relationship between in-field infestations and adoption rates or even features of the landscapes surrounding the fields we sampled. Importantly, our sampling revealed that ECB populations persist in some parts of the state, remaining about the same as in 2000–02 (Bohnenblust et al., 2014). By calculating the economics of production for the different *Bt* and non-*Bt* hybrids studied, we were able to determine that in many parts of the state, particularly where ECB populations were negligible or absent, non-*Bt* hybrids were more profitable, largely because of their lower seed costs. In areas with stronger ECB populations, *Bt* hybrids made more economic sense, but they were not guaranteed to be more profitable, again because of the high seed costs (Bohnenblust et al., 2014).

Given our results, we have been advocating to growers in Pennsylvania that their economic bottom lines could benefit from a better sense of their local populations of ECB. Growers should assess their local populations to know whether or not they are gaining value from planting *Bt* hybrids (Bohnenblust et al., 2014). Blindly planting *Bt* hybrids without regard for the population's size is missing an opportunity to maximize profit while taking advantage of possibly historic lows in pest populations.

Western corn rootworm, *Diabrotica virgifera virgifera* (LeConte) (Coleoptera: Chrysomelidae)

Western corn rootworm (WCR) is currently the most significant corn pest worldwide. The costs of WCR damage and control are estimated to total about $1 billion (Gray et al., 2009). This pest species is extremely adaptable and has evolved resistance to soil-applied insecticides, crop rotation, and, most recently, transgenic *Bt* hybrids (Gassmann et al.,

2011, 2014; Gray et al., 2009). WCR is a pest of continuous corn production, and in Pennsylvania and other mid-Atlantic or eastern states, it is easily controlled by rotating corn with soybeans, alfalfa, or other nonhost crops; WCR lays its eggs in corn fields, and when these fields are planted to a nonhost crop the next season, WCR larvae cannot feed and die. Therefore, crop rotation provides an inexpensive, reliable, cultural control alternative to *Bt* hybrids or soil insecticides (Tooker & Difonzo, 2013). Nevertheless, some Pennsylvania farmers who rotate continue to purchase *Bt* hybrids targeting WCR, buying protection from which they gain no value.

In 2014, colleagues and I learned of three farms in Pennsylvania that had greater than expected damage from rootworm larvae to *Bt* hybrids targeting WCR. This damage occurred in fields that were planted to corn for at least three years. We visited these sites to characterize root damage and found more than 2.5 of each plant's 3 nodes of roots chewed away. We also tested the damaged plants with gene check kits (i.e., Quickstix) to confirm they were producing the appropriate *Bt* toxins (they were), and collected adult beetles (Tooker, 2014). With laboratory assays, we are in the process of determining if the beetle populations we collected are resistant to *Bt* hybrids.

From a practical perspective, however, whether these beetles are resistant does not matter; resistant populations are mostly an academic issue. Large populations of beetles are problematic regardless of resistance, and farmers should take definitive steps to reduce their size. Fortunately, in Pennsylvania crop rotation is very effective at eliminating WCR populations; we do not need advanced insecticidal technology to control this pest species. In this case, just understanding biology and rotating to disrupt the pest life cycle are adequate. This is how IPM is supposed to work: use any means necessary, the less toxic or expensive the better. Rotating crops to control rootworm has been my recommendation to any growers who will listen; rotate your crops and the problem will go away.

Gray garden slug, *Deroceras reticulatum* (Müller) (Mollusca: Gastropoda: Agriolimacidae)

The final pest I will consider is slugs, which in Pennsylvania crop fields are a complex of four species, the most damaging of which is the gray garden slug. This pest species, also accidentally introduced from Europe, has been in the US for about 170 years and has become particularly problematic in no-till crop fields. Farmers manage approximately 1.5 million acres of Pennsylvania croplands with no-till, including about 75% of soybean and 65% of corn fields in the state. Slugs, one of the greatest challenges to no-till in Pennsylvania (Douglas & Tooker, 2012), thrive in the stable habitat provided by no-till and benefit from the moisture typical of spring and fall in mid-Atlantic states. In spring, slugs attack corn, soybean, alfalfa, and even canola seedlings, whereas in fall they attack small grains and various cover crop species (Douglas & Tooker, 2012).

Our research has revealed that ground beetles, also known as carabid beetles, and other predators can help control slug populations. In fact, we have found an inverse relationship between slug and ground beetle populations, meaning that when many ground beetles are present, we find very few slugs, and vice versa. This pattern suggests that fostering ground beetle populations should help farmers decrease slug populations. And some of our recent

research indicates that this is true, but we also found that seed-applied insecticides can disrupt the benefit of predators for controlling slug populations.

In recent years, neonicotinoid insecticides are becoming increasingly common on corn and soybean seeds. In fact, from 2004 to 2011 the percentage of corn seed in the US that was coated with a neonicotinoid insecticide increased from 0 to about 95% (Douglas & Tooker, 2015). These insecticides layered on seeds are absorbed systemically by plants and run through their vascular tissue, protecting the plants from some early season insect pests for the first few weeks of growth. Unfortunately, slugs also attack early in the season but are not susceptible to these insecticides (recall that slugs are not insects but gastropods, in the phylum Mollusca).

We found evidence that slug populations tend to be worse in corn and soybean fields planted with seeds coated with neonicotinoid insecticides. To explore this potential more closely, we conducted laboratory and field experiments in soybeans. In laboratory experiments, slugs were not affected by neonicotinoids, ingesting plant tissue from soybean seedlings grown from treated seeds as readily as that grown from untreated seeds. We also found that when predators attacked slugs that had fed upon plants grown from treated seeds, they were poisoned or killed (Douglas et al., 2015). In the field, we planted quarter-acre plots with either seeds coated with the neonicotinoid thiamethoxam or seeds without thiamethoxam and tracked plant growth and productivity, slug and natural enemy populations, and predation. This research verified that seed-applied insecticides can indirectly increase slug damage to crops by poisoning insects that eat slugs. In the field, plots with neonicotinoid-treated seed had more slugs, which translated to fewer plants per acre and lower yield (Figure 1).

When we considered the influence of predators on slugs, we found that higher levels of predation were driven by having more slug predators in the plots, but plots planted with

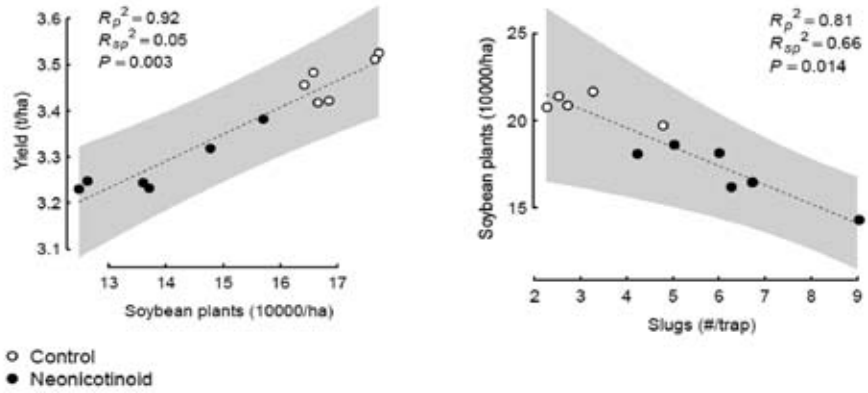

Figure 1. Soybean plots without neonicotinoid seed treatments tended to have higher yield (left-hand panel) because slugs were more abundant in plots with neonicotinoid seed treatments (right-hand panel). Source: Douglas et al., 2015.

soybeans coated with neonicotinoid insecticide tended to have fewer predators and less predation, as measured in the field by a sentinel prey assay; see Figure 2. Moreover, plots with more predation tended to have fewer slugs, but plots planted with insecticidal seed treatments tended to have less predation and more slugs (Figure 2). Overall, in slug-infested plots, soybeans planted with neonicotinoid seed coatings had 19% fewer plants per acre and 5% lower yield. The mechanism responsible began with a lack of an effect of the insecticide on slugs that fed on plants grown from treated seeds. Then, when insect predators ate these slugs, the predators were sensitive to the insecticide now inside the slugs. On average, the slugs contained about 200 parts per billion of neonicotinoid insecticides (Douglas et al., 2015). Importantly, where seeds were planted without the neonicotinoid seed coating, predation of slugs was greater, and yield was higher. These results suggest a major downside to planting neonicotinoid-treated seeds in fields that have significant slug populations. In these situations, the insecticide is doing more harm than good, and a good first step toward pest control in these fields is planting seeds without insecticidal seed treatments.

From these experiments with slugs, we conclude that the default setting of high-input, preventative pest management has a significant downside. Blindly following pest management approaches that were developed with the core of the Cornbelt in mind (not slugs) can be problematic on the fringe, where we have a different pest complex. Our research indicates that growers would benefit strongly from using IPM and managing the pests that they do have, not the pests that they might have. Neonicotinoid seed treatments provide control of secondary pests that may or may not arrive, but farmers tend to know which of their fields have slug problems. In these fields, it is best to use IPM and assess the local populations and respond to them should they become economically significant.

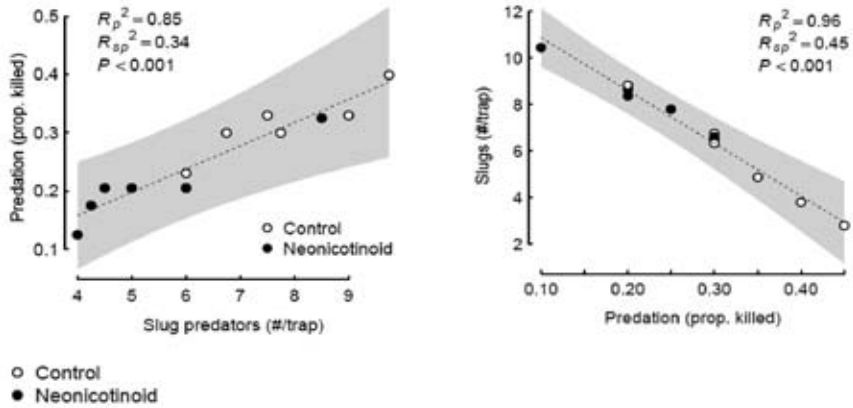

Figure 2. Soybean plots without neonicotinoid seed treatments tended to have higher yield (left-hand panel) because slugs were more abundant in plots with neonicotinoid seed treatments (right-hand panel).
Source: Douglas et al., 2015.

Conclusions

The three pest species I covered here illustrate that the standard prophylactic pest management approach that has been developed for the majority of the Cornbelt has some shortcomings on the fringe. Here, it is best to understand local pest populations, their dynamics, and their biology. By knowing more about pest populations, growers can take advantage of more appropriate control options, minimizing input costs and maximizing profitability. If there are no European corn borer populations in a region, *Bt* hybrids may not be necessary, particularly because some of the other caterpillar pest species that are controlled by *Bt* hybrids tend to be spotty or rare in Pennsylvania and are more economically managed via scouting and rescue treatments. For western corn rootworm, technology does not need to be deployed at all if growers are open to crop rotations that naturally control this pest species in our region. And for slugs, ubiquitous neonicotinoid seed treatments seem to be exacerbating populations by rendering predatory insects less effective, so planting untreated seeds and conserving predator populations can provide an advantage that can resonate to bottom lines (fewer inputs, higher yield, more profit).

Overall, this approach to managing pest populations on the fringe is not pro- or anti-technology. It is just IPM, a knowledge-based approach for managing the pests that growers have, not pests that they may have. This approach is relevant for almost any agricultural system, including the heart of the Cornbelt, but is especially appropriate for growers with smaller fields in more diverse landscapes, such as those found in Pennsylvania and other parts on the fringe of the Cornbelt.

Acknowledgements

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Speaker Profile: http://ento.psu.edu/research/labs

PART V–TIE-UP SESSION

Putting It All Together

Moderator: Steve Pueppke
Michigan State University

Panelists:

Greg Jaffe
CSPI

William Kerr
University of Saskatchewan

Andy Hedgecock
DuPont Pioneer

Tony Shelton
Cornell University

Pueppke: This panel will be different from other panels in the sense that I asked the panel members to join during the conference rather than determined the panel composition ahead of time. Two of them were speakers, Greg Jaffe and William Kerr, and there are two individuals who were not formally on the program, Andy Hedgecock from DuPont Pioneer and Tony Shelton from Cornell University.

We want to have a very interactive, informal conversation at this point. None of them are going to give you monologues. There are no PowerPoints. We want to talk through some of the issues that have popped up over the last couple days. We want to think about the future in particular and in particularly how NABC can help us collectively take some concrete steps forward.

My television set broke in 1979, which is before most of the students among you were born, and I never replaced it. So I don't have a TV set at home, but once in a while at a conference after a long day, I turn on the TV in my hotel room and I look for something totally mindless to get my mind off of the deep conversations. The first channel on the system here in the hotel is HBO. It is channel 2, and up pops a sign that says there is a show called *Vice*, and I thought that this is some awful thing in Philadelphia and they are going to show vice cops. Did anybody happen to catch that last night? It was about GM crops, a story about one of the technology providers, the one where the first letter is an upside-down "W," and the impacts on agriculture and on the world. And all of the issues we have been discussing—framing, societal, technological, and trade issues—popped up in one way or another in that little 15-minute program. And it showed me that these things we have been discussing for the last couple of days pop up everywhere, and you can't even go to your room to get away from them.

I encourage all of you to break in at any time to answer the questions if you want to. The panel up here is meant to stimulate the discussion, but we want to make this very interactive. It strikes me that we have many people in this general dialogue who think they are right. This morning we heard a lot about consumers and people with strong opinions who think they are right about how trade should occur or how technology should be used or the messages that we should be sending to consumers. This is the background on which we are operating, and my question is, how we can advance a dialogue when everybody has these strong opinions and thinks they are right. And it seems to me that this is a question for a lawyer. Greg, that is you, and you have been part of AC21, you have had those interactions. Do you have any thoughts on how we can move forward given the players and their strongly held, often conflicting views?

Jaffe: I am not sure why this is a legal question, but I want to mention a couple of things. One is increased transparency. That is always a positive approach. The more information people have about everything, the better it is and the more transparency you have. I would say that is an important part or an important principle that needs to be part of it. As Bill Hallman said, the debate is framed by people on both extremes who are very vocal, but the vast majority of Americans and consumers fit in-between and don't necessarily have very formed views on this issue.

The second is that I think there is an opportunity for that middle group to be educated in spite of what the extreme groups say, and in spite of what some of the panelists said this morning, I still believe there is an opportunity to educate, and I see that daily in my job. I have spoken at three different Dietetic Association meetings to nutritionists and dieticians who respect CSPI, and I am giving them a different perspective on ag-biotech. At first I saw some raised eyebrows, but then they began to reassess what they had previously thought about that. So with the right audience and respect for the person giving the message, I think you can make an impact. And I am sure Tony Shelton or Margaret Smith from Cornell will tell you that they have impacted the local audiences who respect Cornell scientists. I think part of it is having the right messengers and respect.

The third part, which I think has been missing from this conference, is ag economics. In the end, people largely are economic actors, and I think that for all three issues we have dealt with during this conference there are economic implications and ways to portray them as a win-win propositions.

- *Resistance management* may not pay off in the first year, but the economic data shows that by the second and third year, all of it does pay off. Farmers need to consider that, because in the end they need to take the long view.
- The *trade issues* about regulatory approval, etc., are all about the economics; if planting a crop is beneficial, then there is a way to make that a win-win for both parties in those disputes.
- Similarly with *coexistence*: Biotech farmers get benefit from doing it, as do organic farmers. There should be a way to get a win-win economically for both sides,

and I think we have not stressed that enough. Instead of looking at this as yes or no, right or wrong, black or white, we need to change the dialogue among these groups toward how we can move it to a win-win for everybody. I don't think you will ever capture the people on the extremes on both sides, but I think they don't necessarily speak for the vast majority.

Kerr: One observation I've made in the last few days is that all of us really are people of the scientific method. We all struggle with people who don't believe in the scientific method or for whom it doesn't make sense and whom we have no way to influence intellectually. So if you are trying to figure out how to bridge that gap or how to reach them, how to win their hearts and minds, I don't think we can actually reach them through science.

Pueppke: Andy, how do you approach this? You have a very different background based on where you work.

Hedgecock: Speaking from the industry perspective, industry has been somewhat silent over the last two decades, thinking about their customers as only being the farmers and maybe also the regulatory community, and not focusing on the "public." In the past I don't think we would have been open to having that conversation with the public. It is messy and it didn't go too well, and we need to be alert and worry about so much of it not going well. We need to prepare better. We need to be humble. We need not to be arrogant. We need to be open to that conversation, but the important thing is we need to engage. And it is not going to be a single, leave-behind publication, item, or website, whatever it might be. When we talk about resistance or acceptance, etc., we need to include many perspectives, many facets, and it is not two-sided either. It's multiple-sided. There are multiple facets in terms of people being supportive in some aspects and not in others. So we need to hear all those voices and we need to have more groups like this, where not everything is totally like-minded and equal. I really have liked the idea of having organic growers in these kinds of conversations, because one of the topics that came up today was that the activists and the "anti-ists" are very persistent, coordinated, and strategic. I want to learn from them. Maybe not exactly replicate what they do, but I want to learn from them, e.g., can we show that the Chipotles of the world and their message about not using biotech is pure marketing? So rather than being silent about it and letting the public's opinion crystallize around that issue, I like that there were many alternative approaches suggested in the meeting. I think the tide is turning, but as it is turning, it will get messier in terms of our engagement and our conversation around the benefits and the limitations. That is a big piece, too, that industry has neglected to talk about. We have all been big on the positives but we need to also talk about the limitations. Let us be transparent and let us be real.

R. Connolly, Penn State: This is my first NABC meeting, and I was wondering if you ever considered inviting a Chipotle representative, an anti-GMO person, to come and give their own point of view?

Pueppke: We have in the past. NABC has avoided taking on the really far-out extremes, but thoughtful people who are willing to listen and are respectful and present other viewpoints have been in the room. NABC 15 in Seattle would have been a good example of that.

R. Hardy, NABC: NABC 15 in 2003 was the most accommodating to GMO opponents. Charles Benbrook proposed that he be given one of the sessions and be able to select his own speakers and to chair that session. We agreed to that. We gave the anti-GMO activists a forum integrated into an NABC meeting. We usually aim to have at least one questioning person in the opening session but I am not sure we did that this year. Kathleen Merrigan presented all sides in her keynote presentation, so we may have been remiss in this meeting in not having an outspoken critic on the program.

R. Connolly: This is my own personal experience: I work in the animal and dairy industry, and we invited the Humane Society to come and talk to us, and that was very uncomfortable but also very informative.

Shelton: I think the dialogue is actually changing. How many people saw the *Daily Show* with Jeffrey Smith? We should see that. Google the *Daily Show* and Jeffrey Smith and you will see this incredibly candid presentation where Jeffrey Smith, who is one of the premiere opponents of biotechnology, says that he is not a scientist. He doesn't know anything about this. He is just plain dumb and asks real scientists questions. Then there may be a Cornell plant breeder there who handles this remarkably well. Many of you are under 25 or 30, and where do you get most of your news? On the *Daily Show* and the *Colbert Report*. And check out Dr. Oz as well. So the strategy is changing for communication. *National Geographic*'s March 2015 cover story was "The War on Science." I grew up reading *National Geographic*'s reports about the Amazon, things like this. But today, they are taking this story on. On the cover they give five examples of the attack on science:

1. Man never landed on the moon. You know that was all staged.
2. Evolution didn't occur.
3. Vaccines are causing more problems than good.
4. Fluoridation of water is also a problem.
5. GMO's are not safe.

Not everybody reads news magazines like *National Geographic*. If *People* would take that on it would reach more people. I think Margaret Smith really asked a fundamental and frustrating question that I know many of us at land grant universities have: When we are asked to talk about biotechnology, how do we get our message across? That is really, really difficult.

Wegmans, a supermarket in the Northeast with about 75 different markets, is so advanced that they started a consumer affairs bureau. They were the first supermarket to have this, and they have loyal shoppers and this buys their loyalty. Wegmans contacted us back in 2000 and told us that some of their consumers were coming to them and asking about genetic engineering. Cornell put a brochure together for consumers who had a question. It was very basic. What is genetic engineering? Why is it being done? What

crops are being genetically engineered? Is it safe? We printed 100,000 copies for Wegmans to pass out to their customers, who could write to them with follow-up questions, which they sent to us to answer. One of the ones I remember most clearly was a woman who asked why all these grapes were genetically engineered. And not to tell her they were not because they were big, plump grapes and when she bit into them she could taste that they were genetically engineered. Taste bud analysis! We still contact Wegmans every year to see what the concerns are. Microbial contamination of fruits and vegetables was more of a problem in 2000–10. But around 2012 anti-GMO issues started exploding because of activist pressure. Wegmans took the bold step of putting something on their website in 2014 with the perspective that the crops out there are safe, but that they also offer alternatives, like organics, if people wanted to avoid GMO-containing products. I spoke to our contact there about two weeks after they put this on their website. We had helped them develop the content, since their original draft, while meant to be balanced, contained some GMO bashing. We were told that they got absolutely blasted. Some people wrote that they used to trust Wegmans but don't anymore. Over time the comments and questions became much more balanced. So things are changing. It takes bold moves by groups like Wegmans to get this out via websites or through newspaper reporters, such as the *New York Times*'s Amy Harmon, who has done some really nice work on biotechnology. So the conversation is changing, but we are still in the minority, and we still have our backs against the wall on this. How can we get out and be more proactive?

Hedgecock: How do we draw in folks who are either neutral or negative on the subject to this kind of session? Industry and universities can invite them to have this conversation. Bill Nye the Science Guy was kind of neutral, trending negative. Then Monsanto invited him in for a conversation, and after that he wanted to spread the news about this issue of GMOs. He engaged journalists who are open to hearing and talking and writing about it. As scientists we have been afraid to engage journalists. If we start to have conversations and relationships with journalists and provide them information, they will turn to us if they need a reliable source. Here is another example: I was at a workshop, *Public Interventions in Life Sciences*, this last month in DC, talking about the public trust in science, and I found out that the American Association for Advancement of Sciences is looking into going to museums and science organizations within larger communities or cities and having these conversations and engagements. So one of those things we can do is to invite people to seek out such programs, try them out, and take it from there.

Jaffe: I was just going to add about Wegmans that if you haven't gone to their website I would recommend everybody go and read their frequently asked questions. I was, like Tony, a reviewer for that site and made some comments, and I think what makes it so persuasive is that it is very factual and written very much with their philosophy of marketing in mind. Danny Wegman is an organic farmer and lives on an organic farm, and so they felt very strongly they should support all farmers and that all farmers have difficulty with producing and marketing crops. But while he lives on an organic farm, he also feels very much for the farmers who aren't organic, so he can be very persuasive to Wegmans

customers. Wegmans doesn't just print and reiterate what Grocery Manufacturers of America (GMA) says. They actually looked at why it is important to their customers

Shelton: Wegmans really promotes organic as well. You don't find many GM and organic labels, but they are against regular consumers paying extra for the label. They say that if things are labeled GM-free that is enough, that serves a particular market equivalent to the organic market, but it avoids having labels that mean additional cost to the consumer.

R. Hardy: It is tough to fight the wars of the past. I am not sure how much we gain by continuing to fight those wars. We need to focus on minimizing the future negatives and maximizing the positives. We have heard that stacking herbicides is going to be good for the short term and not so good in the long term. Do we collectively have any recommendations in terms of herbicide stacking? Tough issue, but do we have ideas?

R. Roush, Penn State: I really would want to see the justification of particular stacks, because the experimental data clearly shows in specific examples that there is a problem with mixtures of pesticides and herbicides of any kind. It is a deceptively simple strategy: Surely if an insect or weed is resistant to one, you can kill it with the other. But the devil is in the details. We haven't seen the details. Experience with rye shows that you can make both pesticides fail in exactly the same time if you use them as a mixture. That is to say, they may work for a five-year period and then both stop working. You lost both of them. There is no improvement over using one for five years and then going to the next. The potential is that this strategy actually knocks the herbicide out faster rather than the resistance. The nuances of it are very critical, and I don't think this has been fully appreciated.

Jaffe: And we got a good dose of that in the luncheon presentation with John Tooker—I mean in a good sense. I challenge the people in this audience to raise their voices. I work in Washington, where some of these decisions are made, and they don't hear enough from scientists and if they don't hear from them about these issues, then the voices they hear are only the voices of industry. I can give the example of the *Bt* corn rootworm framework that Jack talked about very briefly here. I looked at the docket and the comments in that docket: all the farmers are against it, and all the industry is against it. My comment supported it, as did some academics who submitted comments. I made a lot of phone calls to academics and asked them to submit comments. That will be helpful. I understand everybody is busy, but as somebody who has worked at the EPA, actually wrote a rule and looked at and reviewed those comments, I must tell you that they are very, very helpful to the people in regulatory agencies, the scientists who want to do the right thing but need the support in those dockets to do that. I strongly suggest that when you have relevant scientific evidence you provide that to the agencies, provide those points of view, because they do help in the decision making.

D. Mortensen, Penn State: I appreciate that comment, Greg. I would just say that as a person who has committed a lot of time to doing just that on the issue of stacked trait herbicide-resistant crops, there is within the science community a pretty strong push-back and rounding of the wagons because they want to have one voice on the way we

do things. I can tell you that from my own personal experience and that of some of my coauthors that having an outside view on an issue may get you mentioned in scientific publications, but then you find you are no longer invited into the discussion when a group of scientists are making decisions or recommendations. It is my view, after reflecting on this for the last three to five years, that the science community needs to really open up and have a conversation about data and the biases that go into the data we collect, the data we leave on the table, and the data that we never even collect. My view is that the science community has not been very frank and open to having these discussions when there are alternating views on some of these subjects. I think my colleagues would agree.

C. Mallory-Smith, Oregon State: I want to follow up on that, and I guess I have to echo what Dave has said. I will speak from the Weed Science Society's perspective. There is a lot of push-back for anybody who is outside the main stream in what you want to present. I think Dave and I could both comment on that, and I believe strongly that there was a lot of input given on some of these considerations within the regulatory system from scientists, which has not been acknowledged or recognized among all the other overwhelming positives they received from an industry push. I mention this because many of us commented on 2,4-D stacking, which is actually a really bad idea if you want to talk about resistance management, because 2,4-D is not going to control grasses. My prediction is that we are going to see a whole bunch of resistant grasses come out of that system. But I do not think it is because that information wasn't given to the EPA.

Pueppke: Let me raise another point related to Lynn Clarkson's comment about the consumer, the customer and making sure that you deliver to the customer what the customer wanted and or needed. A couple of other people from the business side agreed. We also heard it from Cargill. I have spent my whole life in universities and I have sat through a lot of job interviews where we have interviewed administrators and deans and other leaders in what my college used to call Life Science and Natural Resources, the focus of the land grant system. I don't think I have ever heard anybody talk about the consumer being the customer. We internally justify ourselves in my recollection in two ways:

1. There are starving people in the world. The population of the world is growing and we have got to feed people.
2. There is great allegiance to the agricultural production community. People who produce the materials that in turn make the food one way or another.

I think these are different ways of looking at the world. And at least where I live, in the university, we don't think about it the way some of the major players think about who we keep an eye out for, who the ultimate customer is. Does anybody have a perspective on that?

R. Roush: I think that our primary obligation is to the public sector, looking out for the best interests of the farmers. It is often claimed by people in industry that they have the biggest interest in managing resistance because they have the most to lose. A simple little bit of bookkeeping will show that that is not true. If an individual land owner is going to use any chemical, industry will want to get profit out of it. The companies share in the farmer's

profit. It is the collective weight of what the farmer is going to lose. This happens time and time again, where the collective weight of what the farmer is going to lose is much greater than what the company is going to lose. We have examples of that in the cotton industries in Mexico and Northern Australia. When the company left, farmers went out of business, just walked away from the land. The challenges of business really weigh heavily on the land holders, not on the companies involved, so that has to be our principal concern.

R. Giroux, Cargill: In our case we have two customers. We have the farmer customer, and our goal is to help farmers prosper. We also serve almost as middleman to the next customer, the brand food company, the grain manufacturer or the export customer. So we are in an interesting position, right? Two customers, generally they want the same thing, but they don't always. That is why you see a company like ours get into this position of having to give all customers what they want. We must be flexible. But it never changes the fact that we are always going to advocate first to help the farmers prosper, then give the other customers what they want. That is a difficult situation to be in.

L. Clarkson, Clarkson Grain Company: I echo what Randy said. We have tried to find out what the customer on the buying level wants, relate that back to the farmer, and it only works if the consumer is willing to pay more for some differentiation.

Shelton: Working at a land grant university, I think about who my customers are. I have had some discussions, and it is somewhat of an unpopular view, but I say my customer is not the farmer. My customer is the public, the good of the public, and I work for the public good through farmers by trying to get them to use better practices that are safer for the environment and produce better food for the general public. It is always easy to say that we work for the farmers, but that doesn't sit right with me. I work for the general public. When we think about this technology, move this technology along, and we know that scientists and universities get grants and publications and graduate students, things like that out of it, I sometimes I think we lose the focus of who our public really is.

Pueppke: I have been with land grants at least half as long as Tony has, and it is very interesting, because for a long time we in agriculture—I use this term very deliberately—bellyached that society didn't care about food and agriculture. It was all taken for granted, and nobody cared about us and nobody gave us any money and we didn't have any rent money. Then about ten years ago society woke up, the food movement came along, and suddenly we are hearing about local food and organic food and all this other stuff we are talking about here, and we started bellyaching again. They don't see it the way that we do, their opinions aren't based on science, and we are trying to do something and they don't like it. But we don't want to listen to them. We want to do what we want to do. I guess I am betraying my view that we need to do an awful lot of listening in the land grants about what society wants, even if we don't have to do everything they want. We have perspectives and skill sets that are pretty unique, and I think we have a great opportunity now that there are people who really care about food. Most of those people don't come from an agricultural background. They are not science-literate. Most of them would

disagree with people like me on a lot of details, but the good thing about the university is that it is a comfortable place for those discussions. It is a lot harder in other venues to do that, and my recommendation would be that the contribution universities can make is to provide a public forum for those discussions.

T. Harding, Lehigh Valley Organic Growers: I have always looked at this issue of client or customer or student in the sense of that they are all members of a community of stakeholders, and I see no need to define specifically who the client is at this point as long as we remember that all of us are stakeholders in this discussion, that all of us are very much involved, and whether this is good or bad science, we must communicate as stakeholders. The new corporate model looks at every member of the chain as a stakeholder, while the old model only dealt with shareholders, those who hold stock. I think we are now looking at a very different chain. We are looking at a shift in some of the business schools we have had a chance to speak at, we are looking at a committee of stakeholders, and whether we are on the academic side or on the business side or the student side, or for that matter the ultimate client side, we all are stakeholders, and I think we need to think differently about how and to whom we communicate.

I want to pick up on one other issue, and that is the businesses that have really bought into serving the stakeholders environmentally, socially, and economically. These businesses are much more profitable than those which abuse the rules, who don't care about stakeholders, and who really don't care about who the client is. The land grant system for me was a very special place. My extension agent was my best teacher. Today I probably couldn't even find an extension agent, and that is a shame. I had a meeting with the dean at North Carolina State University recently and told him that he needs to start listening to the whole of the stakeholder community, to remember the mandate of the land grant. That there is a great opportunity at the university, and to open it up to all stakeholders. Don't worry about what they are or are not going to say. By all means, keep the extreme right and left out of the situation as much as you can, but make sure you are listening. The biggest problem I have when I talk to a client or to a member of the academic community is that I'm not even sure if they are listening. Sometimes we don't listen well enough to really hear the message the stakeholders are telling us. So I would suggest that we open it up. Transparency is the new word. Authenticity is another new word. And I think it is really critical that we look at it as a community of stakeholders and that we look at it as doing work for the better good of all.

R. Welsh, Syracuse University: I just want to say two things. I came out of the land grant system. I got my master's degree in social economics from Florida and my Ph.D. in rural sociology from Cornell. I have worked for USDA and for not-for-profits. Now I am working at a private university. At Syracuse I was hired to start a food studies program, and my students are passionate about food. They want to know everything, and a lot of them have come in with the Michael Pollan bias, as I'll call it. Or they saw the film *Supersize Me*, but they are still very, very smart, inquisitive people. My feeling is that the reason we see a lot of these food studies programs popping up in private universities is that we are cutting the social science programs in the ag schools around the country. Rural sociology is a skeleton of what it was, and I see it get pushed down here just to pop up here. I don't

like a lot of what goes on in food studies programs. The humanities really don't have to be as careful, they don't have the same background and they aren't as well versed in the issues, but they are not lacking in confidence. I find that troubling and problematic.

Pueppke: We have some students sitting in the back there. Did you all come from farms? Anybody come from a farm? So most of you didn't, right? There's a whole bunch, so what brought you into agriculture?

D. Perry, Penn State: I am actually from food science, and when you were asking about who is our target, who is the consumer, from the perspective of food science the consumer is ultimately right. Unfortunately the consumer gets what the consumer wants, and that is what drives food science. It is not always the way we want it to be, but that ultimately is how it ends up being. Unfortunately, what consumers want, they don't actually always realize, so they have a mental image of what they think they want. When we then do the sensory tests, results show that things are complicated. What they think they like and what they actually like can be two completely different things. So in talking about what is best for the grower and what is best for the consumer, they can be on par with each other or they can be on completely opposite ends of the spectrum, and sometimes the consumer doesn't even realize that. So unfortunately as much as we want to believe it is black and white, there is a lot of grey. What I like in the morning might not be what I like in the afternoon, so even within one person preferences might change; and so when we are talking about the ultimate goal we are after, unfortunately it is going to shift. It is going to evolve, and establishing a system that is more open to this and opening the lines of communication I think are going to be most beneficial.

Pueppke: Very good. Can another student tell us why you are in agriculture if you are not from a farm or food sciences?

M. Hanlon, Penn State: I am in plant biology at Penn State, I think there are five of us from plant biology, and we are very basic researchers. My background is biochemistry. I happened into plants and agriculture because it was fun. It is more fun to do research on plants than it is to kill mice. I enjoyed that more, and then I found that there is a lot of opportunity for research. There are a lot of questions we don't know the answers to. Plants are interesting to do research on. And I think for a lot of us being at this conference has been eye-opening. There are things I never think about. I only think about consumers because I am a consumer. My friends are consumers. My friends approach me for opinions on the things in question, but I think my being here has taught me that there is something lacking in both undergraduate and graduate education. As biologists, as plant biologists, as agricultural researchers, we don't see the whole picture. I work on something very specific, and I know that inside and out, and I know all the people working on it. I can say that when we write grants, when we write an NSF proposal, we always talk about our objectives, which are to feed the world, to do all these grand things. Are we really doing that? When I find that gene X has this effect, am I feeding the world? No, not really, but if I admit that I won't get any money.

Pueppke: But do you think about it?

M. Hanlon: I think we want to think about it in that grander way but it is really hard to do. When you talk to anyone here who is at a different level—from very basic research to distribution to interacting with consumers—how does one person integrate all of those levels? I don't think you can. I think they are important to be aware of, but should I be trying to figure out my role as a young scientist going forward? Should I just keep my head down and continue to do good science? And if I do well in science and I have credible findings and I gain some public credibility, then maybe people will listen to me? I think that is a question a lot of us struggle with.

Pueppke: Do Penn State and your department help you think through those things? I understand the nature of graduate school. Are you going to get it later after you graduate, figure out what you are going to do?

M. Hanlon: I think we get that if we seek it out. I come from a lab where we have these conversations on a regular basis with each other, with my advisor, with my friends, but I don't think it is something that is structured. I don't think it is something that is addressed radically in graduate education. Because I think it is hard to address it.

Hedgecock: I want to come back to a point that was raised earlier when we were talking about critical thinking. We need to teach critical thinking, not just a subject matter or a direct framework on how to critically think, not to be a specialist, and then get credibility instead of being seen as someone who could put things into context for the bigger picture. I would say start doing that now. You already have those conversations. It is critical for people who are passionate about their work to go ahead and do it now. It is in groups like this where we try to put things in context, where we may be an expert in one or two things and other people are experts in other areas, and we can shift things and help mold our contextual definitions. So don't wait. Start doing it now and then your network will help.

J. Newsome, University of Arkansas: To expand on what Molly just said, this contextual thinking is lacking in our graduate program, at least from what I have explored.

Pueppke: Which program are you currently in?

J. Newsome: Plant biology. I think it would be really nice to see more interdisciplinary connections and collaborations. I feel that it would help us as graduate students to be forced to work with others who have expertise in different niches and different areas so we don't get too specific early on when we go into a Ph.D. program and further on into our career. We are working on one particular disease or one particular organism, and I feel that is really to our own detriment as scientists, because as was mentioned earlier, we don't work in a vacuum. It is really important for us to remember all of these things that we are going to have to work with when we find our results. How are they going to fit into that larger puzzle?

R. Huffman, Ohio State: I grew up on a farm, and apparently I am in the minority here, but I know a lot of great scientists in ag science who didn't, and as was mentioned yesterday, it comes back to education. A lot of the people who didn't grow up in an agricultural setting don't understand the processes of grain transport, for example, and it comes down to high school, graduate, college-level education to give people that understanding of the agricultural community. People come in with no ag background, start on a specific project, and apply for grants, always putting in that really broad intro paragraph promising to increase yields, e.g., by looking at one specific protein—something that may never happen. So I feel that it is important to provide a wider educational background for young scientists to work in a framework. How and where to start are not quite clear to me.

Shelton: I have been coming to NABC meetings since 1993, and I always find them stimulating, and keep wishing that more people attended because it is a forum unlike most. One thing I am going to take away from this particular meeting is the discussion about values. When people have different values they came to through a long process of determination, even if they are not aware of them, those values are part of their core beliefs, and they interpret their reality based on that core. So when you talk with people, you have to understand their values.

I was recently in California, when they were soliciting signatures for putting Proposition 37, mandatory labeling of GMO-containing products, on the ballot. As I was walking around a Santa Barbara farmers' market, a man came up to me and asked me to sign the petition. I told him that this was a complicated issue, and when he asked if I didn't think we had the right to know what we are eating, I answered that it really was more complicated than that. I told him I actually worked in this area, giving him the example of a recent experiment where we grew sweet corn containing the *Bt* protein and we didn't have to spray it at all, had 100% clean ears. The kid replied, "Well don't you think people have the right to know about this, and anyway, I don't even believe your experiment." How do you explain this issue to someone in a public setting? I asked a couple more questions, and then his supervisor came over and asked if I didn't think we have the right to know. To my response that it was a more complicated issue than that, she replied that she had just read a study on the web by some French guy, and it showed that rats get tumors when they eat Roundup. I asked if she knew that that study had been retracted. She said no, but there was another study here, and finally she walked away because she was not getting far with me. I told the kid that if he was asking for people to sign a petition, he might want to first learn something about the issue from both sides. He told me: "Sir, I don't know anything about this, but my girlfriend asked me to help with the petitions. That is the only reason I am here." He had his values, I had mine, and we were both perfectly legitimate.

Jaffe: We talked earlier about science and the scientific method, and I want to make two comments about that: When you think about food, food is something other than science. Most of us don't eat because we have to and because that is the only way we get our sustenance. We eat for cultural reasons. We eat for social reasons. We have religious reasons. Our food choices are not scientific. They serve a lot of those other purposes, and we have to take that into account. Different food choices have different meanings;

something that you might find unappealing to eat might be what everybody wants to eat in Asia. It is cultural, and we have to remember that. What we grow and what ends up as our food might be science-based, but when people choose the food they eat they are not choosing it for a scientific reason. They take for granted that all of it is safe, and they move on to other reasons why they are choosing food.

The other thing I would say is I know that regulation is a dirty word, and we all struggled with it yesterday, but I would tell scientists that sometimes what we regulate and the oversight we have are not all science-based all the time. There are lots of other reasons why government gets involved in regulation, such as market failures or increasing consumer confidence. I know that is something that scientists don't like to hear. Regulation and regulatory decisions should only be made on scientific grounds, but that simply is not always the case. We pass laws and do regulation for lots of other public policy reasons, some of them very legitimate and some not so.

Hedgecock: Here are some final comments: We talked a lot about finding common ground, finding a connection with anyone about how they feel, what they think, what they know. That is a great place to start out. And rather than starting out with the ten reasons why I think it should be done my way, we need to ask questions. How do you feel? What do you know about it? Listen to the issues that might be coming from your neighbors, your friends, your colleagues, really listen. Before you speak, listen. Don't get emotional, don't get offended, never take anything personally. When there is misinformation—and people who feel a certain way will provide their top-ten list—take that as an opportunity to ask if they are aware that a listed study was retracted. Don't tell them whether you are opposed to or for that retraction. If they tell you that it was republished, ask if they are aware it was published in a paid-for, non-peer-reviewed journal? Then take the conversation to the next step, and if you don't have an answer for something, don't make it up. Tell them you see that it is an important question to them and to you and that you will check with a specialist and get back to them with an answer. Those are some of the steps I use for engagement, and I think others might use them as well. Be comfortable and confident. You don't have to know everything. Just go ahead and engage and start the conversation, because that is what is important.

PART VI–THE STUDENT VOICE AT NABC 27

The Student Voice at NABC 27

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Each year, NABC holds a conference discussing issues of agricultural biotechnology in North America. The 2015 conference was about *Stewardship for the Sustainability of Genetically Engineered Crops: The Way Forward in Pest Management, Coexistence, and Trade.*

An important component of the conference is the Student Voice, a program for graduate students from NABC member institutions. Student Voice participants exchange thoughts and ideas on topics related to agricultural biotechnology that they found of special interest. The following report is a summary of our exchange as participants in the Student Voice.

The first part of our discussion focused on science advocacy and education. We acknowledged that one of the hardest tasks for scientists is to effectively communicate our findings to the public. We know that even when talking to close relatives, like our own families, we have trouble finding the appropriate words to explain our research. Unfortunately, many scientists are intimidated by public communication and instead of learning how to communicate more effectively, they choose to avoid work-related conversations with nonscientists. We feel there is a need to increase communications

[1] Co-presenters of the *Student Voice Reports.*

with nonscientists. The debate about genetically engineered crops during the past few decades shows that we need to better communicate the real dangers and benefits of biotechnology for society. We need to de-mystify science for the public and educate them on the facts behind scientific discoveries. Especially in a time when funding for research is closely connected to the public perception of it, we will only benefit from engaging in these discussions.

Even though we want to encourage our fellow scientists to engage with the public, we recognize that it is hard to explain science and genetic engineering if the audience has only limited knowledge of basic concepts in biology, especially genetics. We therefore agree with a note from Dr. Mallory-Smith's presentation about the importance of early and thorough genetics education for school children. Knowledge in genetics has become more important than ever before. We live in an era where we regularly encounter genetically engineered crops and where gene therapy is becoming an option for treating disease. People are only able to grasp the concepts behind these new technologies if they understand genetics. Education is the first step toward being an informed citizen who is able to make wise decisions about the use or consumption of products or techniques that result from scientific advances. We therefore ask all NABC participants and readers of this report to talk to their children's teachers and other parents about the importance of genetics education and the need to teach this subject to our children and grandchildren.

The second part of our Student Voice workshop discussed the need to change the focus of the current science and discussions about genetically engineered crops. The main body of scientific publication dealing with genetically engineered crops investigated the safety of these crops for human consumption and the danger of outcrossing. These publications were able to alleviate most, if not all, concerns about their safety and showed that people can safely use genetically engineered crops. Considering the wide use of genetically engineered crops around the world, we suggest shifting the investigations away from safety for humans to their effects on other organisms. Currently, major concerns in the scientific community are populations of herbicide-resistant weeds, effects on non-target organisms, and beneficial insects, such as pollinators. We hope to see more discussion about these effects rather than focusing again and again on safety for human consumption, while safety is well-established for the approved genetically engineered cultivars. We especially ask for more collaboration between ecologists, microbiologists, entomologists, and weed scientists to obtain a better picture of these complex effects on multiple organisms.

In addition to our more general suggestions about communicating our science, genetics education, and updating the focus of the discussion, we also have a more specific suggestion for future NABC conferences. We would like to see an even broader array of participants during the years to come. The sciences of agricultural biotechnology and genetically engineered crops arewell established, and we reached a common consent about their safety among scientists. We therefore think that it is time to invite more diverse groups to attend this conference. We need to convey these findings more

effectively to people who are not biologists or working in agriculture. We should work closer with social scientists to find effective ways of reaching out, and the NABC should invite more experts in the media, social sciences, or humanities to participate in the conferences. Maybe it is even time to open the meeting directly to consumers as we need to inform them about our findings and could better cater our research to consumer concerns if we began creating closer ties with nonscientist communities.

At the end of this report we want to thank the NABC for the Student Voice travel grants that enabled most of us to travel to the conference and Dean Gary Thompson from Pennsylvania State University for hosting this year's NABC conference and his great hospitality.

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